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Toads, Dome, and Lampposts

An Ethnographic Study of a Smart City in the Making

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-------*An Ethnographic Study of a Smart City in the Making*

Jingwen Yin

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To my beloved parents!

Abstract

This thesis is an ethnography of the making of a smart city initiative called Open Programmable Harbour City (OPHC). The aim of OPHC is to build a programmable testbed to enable everyone to experiment with their smart city applications. This original research aims to address three gaps in the current smart cities literature. It first seeks to understand the actual innovation processes of this smart city initiative. It then takes a unique angle to investigate the roles of vision in the innovation processes. It also focuses on citizen participation in the OPHC project. In order to interpret the data, the research went through an *iterative-inductive* process to assemble a theoretical framework. This framework draws on conceptual tools from two intellectual sources: Transition Studies (the socio-technical perspective) and the Sociology of Expectation. The researcher conducted 49 main participant observations in and beyond Harbour City; 24 formal interviews and 19 key informal interviews over 17 months to collect data.

The data reveals three stages (emergence, implementation, and diffusion) in the innovation process of OPHC. The results show that OPHC did not emerge in a vacuum. Instead, it is a *configuration* of people, artefacts, and expectations that *survived* in the selection environment at the *niche* level. This *configuration* was relabelled as a smart city project. At the local level, the implementation of OPHC was formed of loosely coordinated parallel niche experimentations. At the global level, the diffusion of OPHC was mainly about spreading its vision. The diffusion produced some dynamic results in both vertical and horizontal directions. Apart from understanding the mechanisms of the innovation process, this research also pays attention to roles of citizens and vision in the innovation process. It suggested that citizens had a limited role in making smart cities. The vision plays dynamics and sometime paradoxical roles in the innovation process. Overall, the thesis makes both empirical and theoretical contributions to current smart cities literature, and open many doors for future explorations.

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This research would not have been possible without the generous help of certain people. I would like to thank those who helped me on this journey. I first would like to thank both my supervisors: Professor Keri Facer, without whom, I would not have returned to the UK and started this journey. I thank her to helping me refine the initial research focus, putting me in touch with some initial local informants, teaching me how to communicate my ideas, and challenging me in the process which built up my strength. I would like to thank Professor Thomas Osborne for providing me with initial theoretical guidance and refining arguments. Although, I adopted a slightly different theoretical approach in the end, that original training got me started and gave me the courage to assemble the theoretical framework for this thesis. I also need to thank both of them for reading my thesis again and again even though my English is not perfect all the time.

I would like to thank the participants from the smart city project, OPHC and elsewhere in Harbour City. I thank them for welcoming me, allowing me to collect data, tolerating my presence, talking openly and critically about the smart city project, OPHC, and providing me unconditional support beyond that which a researcher could normally expect, such as giving me a lift when I collected data late at night, inviting me for tea and dinners, providing moral support, etc. For reasons of anonymity, I cannot thank them using their real names. But, I would still like to mention their titles here: I want to thank a civil servant from the Harbour City Council, a co-director from Straw House, the designer of the Toad, and many others. Because of you, the data collection was an enjoyable process. I also need to thank my engineering friends from different labs in the University of Bristol, especially Dr Grandet who patiently explained many details of the technologies involved in the OPHC project to me.

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Finally, I would like to thank Harbour City. People often say the city you live in your 20s will affect your whole life. Life made me encounter Harbour City and this city has left a mark on me.

Author’s declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University’s regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award.

Except where indicated by specific references in the text, the work is the candidate’s own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

Signed: …………………… Date: ……………………......

Table of contents

List of Figures

List of Tables

Abbreviations and Acronyms

ANT	Actor-Network Theory
DC	Digital Challenge
DCIIC	Delta City Industry and Information Commission
DCMS	Department of Culture, Media, and Sports (UK)
FCO	Foreign and Commonwealth Office (UK)
HLA	High-Level Architecture
IoT	Internet of Things
MIIT	Ministry of Industry and Information Technology (China)
MLP	Multi-level perspective
NFV	Network Function Virtualisation
NV	Network Virtualisation
OPHC	Open Programmable Harbour City
SCC	Super Connected Cities
SDN	Software Defined Network
SOE	Sociology of Expectation
SOF	Sociology of the Future
SNM	Strategic Niche Management
STS	Science and Technology Studies

The Main Cast

Actors

Chris
The Chief Manager of OPHC, from July (2014) to June (2016).

Ruby
A civil servant from Harbour City Council.

Susan
A world leading optical network Professor from the Harbour City University and the Chief Technology Designer of OPHC.

Innovation teams

OPHC engineering team
A group of 2 to 4 engineers lead by David. They in charge of implementing and designing OPHC programmable testbed
.

OPHC business team
A small team response to promote OPHC and align partners, including Chris and Rufus.

Data Dome team
A group of actors lead the Data Dome innovation, including Peggy, Jim and Henry.

Citizen Sensing team
A group of actors lead the Citizen Sensing innovation, mainly including Camila, Stein, Judy, Lucy, Maria.

Vertical Diffusion team
A group of actors spread OPHC to general global smart cities audience, mainly including Chris, Ruby, Peggy, David, and Susan.

Horizontal Diffusion team
A group of actors spread OPHC to another local smart city niche in Delta City, mainly including Chris, Green, and Ruby.

Institutions

Box
A business incubator in Harbour City and a local host partner of OPHC.

DOCK
A creative digital centre in Harbour City and a local host partner of OPHC.

Harbour City University
A university in Harbour City and one party of OPHC joint venture.

Harbour City Council
The local council in Harbour City and one party of OPHC joint venture.

Science Museum
A science education centre in Harbour City and a local host partner of OPHC.

Straw House
A community engagement organisation in Harbour City and a local host partner of OPHC.

Artefacts

Programmable testbed
A city-scale programmable infrastructure of OPHC.

Data Dome
The first application of OPHC, a data visualization device.

Toad
A Citizen Sensing application co-produced by Straw House and local communities in response to domestic damp issue.

Cities

Harbour City
A middle-size city located in England (UK).

Delta City
A mega city in China and sister city of Harbour City.

(Note: Above, I have only listed the key actors of this research. The full list of actors in each episode of story could be found at beginning of each empirical chapter.)

Glossary

Active Node: A "Node" is a network communication terminology describing the physical point for network traffic conjunctions. "Active" indicates "programmable". In this research, an "active node" means a network node that can be programmed.

City OS: This is a piece of software designed by Light Speed. It is the software part of the OPHC programmable infrastructure. It aims to orchestra heterogeneous networks and resources in a city.

Network Emulator: This is a technique to test the performance of a real application over a virtual network. It can increase the experimentation and scale-up capacity of a network.

RF Mesh Network: This is a Radio Frequency Mesh network. A type of communication network that is made up of radio nodes and these nodes can be organised in a mesh topology.

Software Defined Network (SDN): This is a network communication terminology. For each network component, it decouples the hardware from its own control plane, and uses a centralized control plane to manage the behaviour of components in a network. Such separation can enable the network programmability in a more efficient and easier manner. It also addressed the challenge of managing components from different infrastructure providers that offer different standards.

(Note: Above, I have only highlighted the key technological terminologies of this research. More technological terminology is explained within the text or inserted below the text as footnotes.)

Chapter 1

Introduction

1.1 Prologue

Chris stands on the stage of a smart cities conference in Delta City (China). Today[1], he will give a speech about Open Programmable Harbour City (OPHC). OPHC is a newly launched smart city project in Harbour City (UK). Since Chris took up the role as a Chief Manager of OPHC, he has travelled around the world to talk about OPHC, and this is the second time within 6 months he is in China. China is frequently mentioned in the smart cities literature, mainly due to its rapid urbanisation and opportunities for smart cities businesses. Despite his jet-lag, Chris confidently stands in front of his audience. His voice calm and persuasive, like a missionary or prophet of the future. He tells the audience that OPHC is a joint venture smart city project in Harbour City. The vision of the project is to build the world's first city-scale programmable infrastructure which will enable a wide range of local and global people to experiment with their own smart cities solutions. This vision stands out in the current smart cities movement because it does not aim to deliver a whole package of smart city solutions to people. Instead, it aims to provide a platform for people to experiment with their own smart solutions. The key technological enabler behind it is the promising networking technology Software Defined Network (SDN), which has the potential to bring revolutionary change to the current networking industry. Apart from its technological vision, OPHC also put citizens at the core of its principle. This is evidenced in the many roles that OPHC has allocated for citizens. For example, it has promised to open its testbed for everyone to

[1] It took place at 18 March 2016.

conduct experiments. It has already transformed a Planetarium show space into a Data Dome for local citizens to view and interact with their urban data. Moreover, it also cooperates with a local community organisation, Straw House, to co-produce the Citizen Sensing application with local communities.

Why is Chris giving a speech in Delta City? What is the Open Programmable Harbour City (OPHC)? How did it come into being? Who drives the project? Is it an already built smart city or merely a vision? What is programmable infrastructure? What is state-of-the-art SDN? Who will actually use the infrastructure? What is Data Dome? What is the Citizen Sensing application? Who is Straw House? To what extent can citizens participate in the innovation process? Will Delta City audiences accept the vision that Chris is trying to sell to them? Readers might already have a thousand questions in their heads. This thesis presents ethnographic research about OPHC. It will present the detailed process of OPHC's emergence, implementation, and diffusion. As the stories unfold, you will not only find answers for the above questions, but also a deeper understanding about the making of an actual smart city. You will not only know the characteristics, mechanisms, and challenges of building a smart city, but also have fresh insights into the role of vision and citizens in the innovation process. You will not only feel innovators' pulses, hopes, and ambitions in building a smart city, but also see the challenges of realising their ambitions, learn which dreams crashed, see expectation becoming hype and understand why OPHC is a failure, but not a failure.

1.2 Why this research matters

This is a timely piece of original research in the midst of the current smart city movement. Readers might be disappointed if they expect to find conventional smart cities arguments in this thesis, for example, that smart cities are imposed by technology corporations and are characterised by a lack of citizens' voices (Townsend, 2013). This way of building smart cities has generated a lot of concern: for instance, concerns that citizens in many proposed smart city visions are simply marketing devices, that the innovations are mainly intended for urban entrepreneurs (Holland, 2014); that the smart city is another form of neo-liberal urban utopian ideology (Kitchin, 2015); that smart cities might generate issues of surveillance, control, and privacy (Vanolo, 2013). However, what we lack in current smart city research is a detailed understanding of the actual innovation processes of a smart city project and a role for citizens in the processes. This research specifically addresses these gaps by providing ethnographic research about a local smart city initiative in the making and exploring citizen participation opportunities in detail. Moreover, this research pays special attention to the role of vision in the innovation process. This is an aspect that is often neglected by much smart cities literature. Most current smart cities research treats vision as an object of critique. This way of looking at vision blinds them from looking at what vision does in an innovation process. This is an original piece of research which traces the roles of vision in an actual smart city innovation process. It shows readers that vision is not an external factor of innovation, but an actor in the innovation process.

This research seeks to make both empirical and theoretical contributions to current smart cities literature. Empirically, this research provides first-hand empirical data about the innovation process of a smart city project; a detailed picture of citizen engagement, and the roles of vision in the innovation process. This level of detailed understanding can only be achieved through ethnographic research. Theoretically, this research creatively assembles conceptual tools from two intellectual sources: the social-technical perspective of Transition Studies and the Sociology of Expectation (SOE). They demonstrate their strengths to help understand the dynamic and messy innovation process of OPHC. For example, it will describe the messy emergence of OPHC, its dynamic implementation and diffusion process, and the role of vision in the process. The empirical and theoretical aspects of this research might be of interest for smart city researchers to look at. They might benefit from reading the first-hand, detailed, empirical data and find the theoretical framework inspiring. Scholars from Transition Studies and the Sociology of Expectation (SOE) might also be interested in reading this research. Both theoretical frameworks are based on historical cases and have often been applied to analyses of completed historical innovations. This research applies both frameworks in a real-time, multi-cultural context, and in the context of smart cities innovation, and in return, research might contribute to further developing both theoretical frameworks. For example, this research argues that vision/expectation is an actor in an innovation process. It suggests that hype comes at different speeds at different levels. It finds that *proximity of expectation* is another type of *proximity* that influence the diffusion of an innovation from one niche to another niche (See more in Chapter 8).

This research is not only for academic readers. I hope that this thesis will also be of an interest to non-academic readers, such as smart cities innovators and citizens. For OPHC innovators, I noticed when observing the innovation process, many OPHC innovators joined the project at difference stages and in response to specific parts of the OPHC. They often knew little about the history of OPHC and the overall innovation process. By reading this research, they could gain a better understanding of the innovation that they were involved in and be more reflective about their own innovation activities. Smart cities innovators beyond Harbour City, might also find this research interesting to read, perhaps finding the case of OPHC informative and could learn lessons from it. For example, lesson might be that it is necessary to pay attention to coordination issues in the innovation process; the importance of having a more intentional configuration of citizens; building a more realistic view of the open innovation model; and acknowledging that vision can play dynamic and paradoxical roles in an innovation process. For example, vision can attract attentions as well as damage a project's reputations.

This research might also be of interest for ordinary citizens to read. It is too often the case that citizens have no idea about smart cities innovations in their own city and are unfamiliar with the new term 'smart cities'. The story style of this ethnographic research aims to make the content accessible for ordinary citizens to read. It hopes to open the black-box of 'smart cities' for them. Through reading this research, citizens might learn more about what 'smart cities' mean and build some basic understanding of popular smart technologies. Moreover, this research encourages citizens to reflect on the roles that proposed smart cities could potentially assign them. Are they roles they want? If not, how can they bravely negotiate roles they do want in smart cities innovation processes? And how can they stake a claim in their future, and design a future city according to their hearts?

1.3 Navigating the thesis

This thesis can be divided into two parts: Part I and Part II. Part I consists of three chapters: Chapter 2, Chapter 3, and Chapter 4. Part I provides the research context, methodology, and theoretical frameworks. Part II has three empirical chapters (Chapter 5, Chapter 6, and Chapter 7) and a conclusion chapter (Chapter 8). The three empirical chapters contain stories and analysis from selected fieldwork data which responds to different stages, aspects, and scales in the innovation process of OPHC. They illustrate the emergence, implementation, and diffusion processes of OPHC. The conclusion chapter reflects the overall research.

Below, I provide an overview of each chapter.

Part I

Chapter 2 reviews a wide range of literature on 'smart cities', such as the emergence of the 'smart cities' phenomenon and current research about 'smart cities'. This chapter has two goals. First, it intends to build an informed picture about 'smart cities'. Second, it highlights three knowledge gaps (innovation process, citizen participations, and the roles of vision) in current 'smart cities' literature that this research would like to address.

Chapter 3 is a methodology chapter. It illustrates the process of how this research was carried out, such as the process of sampling, data collection, configuring theoretical frameworks, and data analysis. It also addresses important decisions that I made about the research, including choosing the philosophic positioning, ethnographic approach, ethical concerns. In the end, it reflects on my personal positioning in relation to the research process.

Chapter 4 provides readers with an overview of theoretical framework for this research. The theoretical framework consists of two parts: the socio-technical perspective of Transition Studies and the Sociology of Expectation (SOE). How this framework was selected is discussed in Chapter 3. This chapter takes a step further and reviews key conceptual tools from both intellectual resources in detail. It aims to provides readers with an overall picture of the key conceptual tools of this research in its original theoretical context.

Part II

Chapter 5 shows how OPHC emerged in Harbour City. The story unfolds chronologically in five sub-sections with relevant conceptual tools applied (*configuration*, *multi-level perspective* (MLP), and *prospective structure*) to make sense of its emergence. This chapter shows that OPHC's birth was not in a vacuum. Instead, it was a *configuration* of people, artefacts, and expectations that *survived* in the selection environment at the *niche* level. This *configuration* was then relabelled as a smart city innovation.

Chapter 6 investigates the innovation process of OPHC in Harbour City. Three detailed ethnographic sites studies make up Chapter 6. This includes the site of programmable infrastructure, the site Data Dome, and the site of Citizen Sensing application. It integrates conceptual tools from Strategic Niche Management (SNM) and the Sociology of Expectation

(SOE) to understand mechanisms and challenges in the implementation process.

Chapter 7 studied the diffusion process of OPHC beyond Harbour City. The diffusion of OPHC happened in two directions: vertical diffusion (diffusing OPHC to general global smart city niche) and horizontal diffusion (diffusing OPHC to another local smart city niche in Delta City). It applied conceptual tools from Strategic Niche Management (SNM) and the Sociology of Expectation (SOE) to understand both diffusion processes. It reveals mechanisms, challenges, and paradox phenomenon in the diffusion process.

Chapter 8 is the final chapter of this thesis. It first reflects the smart city innovation of OPHC. It then summarises findings from three empirical chapters in response to three research questions. This is followed by reflection on the limitations of the research and a consideration of future empirical and theoretical research directions. Finally, this thesis ends with some of my own thoughts about technological innovation.

Chapter 2

Mapping the Development and Research Landscape of 'Smart Cities'

This chapter aims to locate this research in the wider 'smart cities' context. It starts by presenting an informed picture of 'smart cities'; introducing the phenomena of 'smart cities', in particular the emergence of the concept, its worldwide adaptation, and the still vague attempts at definitions. It then reviews the current research on 'smart cities', such as the conceptual critique of 'smart cities', and the recent empirical turn in the field. After reviewing the 'smart cities' literature, this chapter further identifies the three gaps in the current 'smart cities' literature that this research aims to contribute to. The first gap is a need to have more in-depth empirical study on the innovation process of a local smart city project. The second gap is a lack of understanding about the role of vision in a smart city innovation process. The third gap is the need to have a more detailed understanding of citizen participation at a project level. The chapter finishes with three foreshadowed questions (Malinowski, 1922) designed according to the three gaps identified to guide the research.

2.1 'Future Cities' and 'Smart Cities'

Human beings have been thinking, planning, and building cities of the future since ancient times (Fainstein, 2014; Moir et al., 2014). Cities generally are "futuristic". City discourses typically draw on future discourses. In English-language literature, there have been at least four waves of future city discourses that can be identified in the last hundred years (Moir et al., 2014). The first wave happened during the interwar period. At that time, modernist planners and architects developed ideas of greener cities in response to the side-effects of industrialisation. The most representative example is Le Corbusier’s (1971) *The City of Tomorrow*. After the Second World War, future city discourses focused on remedying the cities that were destroyed by warfare. In the 1980s, influenced by economic globalisation, future cities became sites intended to support the new cycle of global trade. From 1990 onwards, the rise of the telecommunications and information technology brought new thinking and imagination about the urban future. Today, due to rapid demographic shifts and urbanisation, the world is witnessing a new wave of the ‘future city’ movement. According to a UN estimate, by 2030, 70% of the world population will live in cities (WHO, 2014; Un.org, 2001). In this movement, cities feature urgent economic, environmental, and social problems that need to be addressed by future-oriented solutions (Gabrys, 2014).

There are many ideas about how to build future cities in current public discourses and the academic literature. Research into future city terminology provides us with some insights about the future city landscape. de Jong et al.’s (2015) study of future city policy discourses finds that the ‘sustainable city’ has been the most frequently occurring concept of the future city in academic literatures since 1996. The term ‘digital city’ took off in the early 2000s, but it was replaced by a rocketing interest in ‘smart cities’ in 2009. The ‘smart cities’ idea has gained steady attention in recent years and has surpassed the ‘sustainable city’ in the frequency of academic usage since 2012. The terms ‘resilient city’ and ‘low carbon city’ emerged in 2009 as a result of the global climate debate but neither term has been widely adopted as a future city category. Moir et al.’s (2014) research reveals a very similar usage pattern of future city terminologies. Their study further notes that ‘future cities’ and the ‘future of cities’ combined are the third most commonly used terms after ‘sustainable cities’ and ‘smart cities’. The term ‘future cities’ overtook the term ‘future of cities’ from 2009 onwards, but the former has a more limited focus on the technological dimension (Ibid:15). So, we can conclude that the term ‘smart city’ or ‘techno-centric future city’ dominate today’s policy and research literature.

Of course, the idea that cities could be transformed by technologies is not new. But, the specific connotations of the idea have changed over time. For example, in the 1960s, information technology and cybernetic thinking started to have an impact on the way people thought about and imagined their future cities (Crompton, 2012; Forrester, 1969). At that time, avant-garde architects from both West and East dreamed and experimented with technology enhanced future cities. The former evidenced in the English Archigram movement (Crompton, 2012) which embraced high-tech innovation and pop culture to design the imaginary cities of tomorrow. While the latter could be found in the Japanese metabolisms movement which incorporated traditional Japanese architectural ideas into the Modernist idiom. From the 1980s onward, network cities and computable cities began to appear regularly in urban development plans (Castells, 1989; Mitchell, 1995; Batty, 1997; Graham and Marvin, 2001). Many ideas of technological cities emerged during this period, such as the 'wired city' (Dutton, 1987), 'information city' (Castells, 1996), 'cyber city' (Graham and Marvin, 1999), 'digital city' (Ishida and Isbister, 2000), 'ubiquitous city' (Weiser, 1996; Anthopoulos and Fitsilis, 2010), and the 'intelligent city' (Komninos, 2013). As we can see from these examples, each term conceptualises the relationship between ICT and the city differently. This is mainly because they were inspired by the particular technological breakthroughs (e.g. telematics, the World Wide Web, broadband, and web 2.0, etc.) of their time (Carvalho, 2014). The most recent term, 'smart city', is another reinvention of this idea which is influenced by a series of recent IT developments, such as wireless networks, enhanced broadband connectivity, cloud-based solutions, smart-devices, real-time data, and the Internet of Things[2] (IoT), and many others (Saunders and Baeck, 2015; Carvalho, 2014).

2.2 'Smart Cities': its emergence, diffusion, and definitions

2.2.1 The emergence of 'Smart Cities'

Where does the idea 'smart cities' originally come from? Holland (2008) and Vanolo (2013) suggest that the concept of 'smart cities' has grown in connection with two academic literatures. One was the New Urbanism literature which started in the US in the early 1980s. The movement raised criticisms of the urban development model based on the usage of cars and urban sprawl. It suggested that quality of life could be improved through reducing overbuilding and land consumption. Many smart cities indicators we refer to nowadays (e.g. liveability, walkability, and sustainability) can be traced back to this movement (Konomi and Roussos, 2017). The second intellectual source is the intelligent city debate; a debate triggered by the phenomenon that many cities around the world have increased their budgets in ICT infrastructure, innovation, and e-governance (Crivello, 2014: 912).

[2] This is a computing concept describing an idea that physical objects are connected to the Internet and able to identify each other.

Both expert discourses might contribute to the early idea of ‘smart cities’, however, the current ‘smart cities’ discourses have mainly been developed outside academic circles by multinational companies, such as IBM, Cisco, and Siemens. These technology corporations are the early advocators of ‘smart cities’. Their arguments are based on the probability that some of the newly emerged technological solutions (e.g. IoT, Cloud Computing) might bring a better future for cities. As private stakeholders, these companies suggest that they have the capacity to make it possible for people to experiment with new ways of living, working, and moving (Crivello, 2014). Amongst these private sector smart city advocates, IBM was one of the earliest smart city promotors. In late 2008, the then CEO of IBM announced a smart city vision as part of IBM’s Smarter Planet initiative. The vision suggested that investing in digital systems in cities was a way to improve a city’s management and lower the chance of economic decline (Wiig, 2015). Vanolo (2014) links IBM’s announcement of its smart city vision in 2008 to the economic crisis the same year. He argues that it might be not a coincidence that smart city discourses seem to go hand in hand with the economic crisis in 2008 because, at that time, cities were facing severe financing cuts and smart technology was regarded as a good solution for cities in crisis (Ibid).

2.2.2 The diffusion of ‘Smart Cities’

The ‘smart cities’ concept has become popular in Europe in recent years. This is mainly due to its association with large research funding (Vanolo, 2014). One good example is the European Horizon 2020 project. Within the project, there are many engineering research themes that relate to ‘smart cities’. For instance, there is a research theme called Future Internet and Smart City. It ties future internet research with the concept of smart cities. It suggests that smart city development could be a catalyst for Future Internet research because a smart city must rely on a good internet infrastructure. In return, the advanced applications coming out of the Future Internet research could benefit European citizens (Paskaleva, 2011). At the time of writing, there are hundreds of smart cities initiatives across Europe. The largest number of smart city initiatives can be found in the UK, Spain, and Italy (Bennett et al., 2016). Each country has different reasons to adopt ‘Smart City’ ideas. For example, in the UK, the national government suggests that there is a huge potential for the UK to take a lead in the current ‘smart cities’ movement. This will be beneficial both at home and abroad. At home, smart technology is presumed to bring better urban services to citizens in the UK. Abroad, the UK has a competitive advantage to provide ‘smart cities’ related products and services. This might bring export opportunities for the UK. According to one estimate global smart city market solutions are expected to reach $400 billion by 2020. The UK government encourages domestic public and private sectors to work together to get 10 per cent of that value (Saint, 2014). In order to support smart city development in the UK, the government provides financial support for smart city investment. For example, the Research Council UK provides £95 million for smart city research. The UK government's national agency Technology Strategy Board (TSB) spent £50 million over 5 years to establish a Future City Catapult centre (Bennett et al., 2016). In 2012, the TSB also launched a Future Cities Demonstration Competition (FCDC) to unlock the promise of the smart city (Buck and While, 2015). In response to the national call, many local governments generated their own local smart city initiatives. According to Caprotti et al.'s (2016) survey, a third of local authorities in the UK with a population of over 100,000 have clear smart city initiatives (Cowley et al., 2017). Amongst them, several cities demonstrated strong commitments to 'smart cities', including London, Milton Keynes, Manchester, Glasgow, Bristol, and Peterborough (Ibid, 2017).

The smart city is not just a Euro-American phenomenon. In Asia, countries like South Korea, Japan, China, Singapore, India, and many others have also generated smart cities initiatives. The largest numbers of 'smart cities' plans in Asia can be found in India and China. According to the estimates, there are almost 300 'smart city' pilots currently under plan in both countries (Saunders and Baeck, 2015). Singapore and South Korea are pioneers of experimenting 'smart cities'. The idea of smart cities' is not new for either country because they both have a long-term preoccupation with introducing the latest technologies into urban development. In the case of Singapore, its journey towards "smartness" started in the 1980s. At that time, the Singapore government set up the National Computer Board (NCB) to computerise the government ministries and developed export orientated IT industries. In the 1990s, Singapore sought to upgrade its workforce and shifted to a more value-added economy. NCB released an important document called: *A vision of an Intelligent Island: IT 2000 masterplan*. In the report, it clearly stated the ambition of transforming the country to an "intelligent island" where technologies would be regarded as a means to enhance national competitiveness and the life of citizens (Mahizhnan, 1999; Hollands, 2008). The technological initiatives at that time included, increasing broadband speeds, integrating IT into the civil service, and developing the world's first Electronic Road Pricing System (ERP). In June 2006, the newly launched 10-year plan, *Intelligent Nation 2015 (iN2015),* envisioned Singapore's future would benefit from information communication. The plan announced an ambitious goal to become the first country in the world to harness information communication. iN2015 had contributed to building the backbone infrastructure for big data analytics, the Internet of Things, and many other components of a smart city. In 2014, Singapore launched the "Smart Nation" initiative. This initiative sought to use advanced technologies to drive its economic growth and improve citizens' lives (Saunders and Baeck, 2015). Due to Singapore's long-time exploration in the area of integrating technologies into urban development, when the 'smart cities' idea became popular in the world, Singapore naturally became a pioneer in the field. For South Korea, its smart city journey started from the Asian Financial crisis in 1997. The crisis urged the South Korean government to upgrade its economic paradigm from manufacturing to service (Shwayri, 2013). The South Korean government regarded urban development as a way to attract foreign investment and expertise. The 'ubiquitous city' idea was embraced by the South Korean government as a consequence of this thinking. The most famous example is Songdo City, which is a start-up city built from scratch. The Songdo City vision is associated with the idea of moving the South Korean economy from too much dependence on manufacturing to international logistics (Shin, 2016). Five years later buildings were rising above the landfill in Songdo, Cisco joined the Songdo project with $47 million investment and promised to wire Songdo from top to bottom (Strickland, 2011). So, South Korea's adaptation of the smart city was associated with its need to upgrade its economic paradigms. The 'ubiquitous city' concept was the initial concept to pick up on and describe this type of urban development and the concept was later replaced by the popular concept 'smart cities'.

There are also smart cities projects in Africa and Latin America. The most frequently mentioned example is Rio de Janeiro's smart city development. Rio's smart city project was triggered by a flood in 2010 which killed 50 people. The mayor, Paes, called in a team of IBM engineers to design a disaster management system (Townsend, 2013). Going beyond the project to deal with the flood, IBM further recommended to build a system that make the city's weather, geological, and civil defence agencies to work together (Lindsay, 2010). As a result, IBM and Oracle developed the famous Rio operations centre which became the heart of Rio's smart city. The mission of the operations centre is to consolidate data from various urban systems for real-time data visualisation, monitoring, and analysis. It is the first operations centre in the world to integrate crisis management solutions and multiple government administrations in one place. It aims to predict, mitigate, and prepare for immediate response to events (Durani, 2017).

2.2.3 The definition of 'Smart Cities'

The concept of 'smart cities' is widespread worldwide, however, the definition of a smart city remains vague. It is very difficult to have a universally agreed definition about 'smart cities'. This is partly due to different people and regions having different purposes and priorities when they pick up the term 'smart city'. Moir et al. (2014: 12) seek to define 'smart cities' in both a narrow sense and broader sense. They argue that the term 'smart city' used in a narrow sense indicates the use of the right hardware, software and technology platforms to solve many urban challenges, while, 'smart city' applied in a broader sense often places emphasis on good city governance, the empowerment of city leadership, smart citizens, and the right investment in smart technologies (Ibid). A group of researchers from Vienna, Ljubljana, and Delft tried a different approach to defining the term. They benchmarked the smartness of 70 European cities and distinguished six smart city characteristics, "smart economy", "smart mobility", "smart governance", "smart environment", "smart living", and "smart people". Many smart cities projects have adopted this classification to guide their smart city constructions (Caragliu et al., 2011; Vanolo, 2013). In a similar vein, Caragliu et al. (2011) summarise several characteristics that are shared by many smart city projects. For example, 'smart city' projects often propose to utilise networked infrastructure to improve economic and political efficiency as well as to enable social, cultural, and urban development (Hollands, 2008: 308); 'Smart cities' often emphasise business-led urban development and seek to achieve the social inclusion of citizens in public services; 'Smart cities' often highlight the role of high-tech and creative industries in long-term urban growth; 'Smart cities' claim to pay attention to the role of social and relational capital in urban development; Social and environmental sustainability are regarded as a major strategic component for 'smart cities'. Most of these smart city definitions and characteristics focus overly on the technological dimension of a 'smart city'. Nam and Pardo (2011) seek to expand the meaning of 'smart cities'. They identify three categories of 'smart cities', with the technological dimension of the smart city as one of them which includes sub-categories such as, Digital City, Virtual City, and Intelligent City. They expand the concept of 'smart cities' beyond the technological dimension by adding another two dimensions: the human and institutional dimensions. The human dimension of a smart city, as its name indicates, includes the human aspect in 'smart cities'. This often covers categories such as learning city and knowledge city. While the institutional dimension of a smart city includes concepts such as smart community, sustainable city, and green city.

2.3 Current 'Smart Cities' research

2.3.1 The conceptual critique of 'Smart Cities'

Conceptualisations of the city of the future have never been short of criticism. Scholars, thinkers, and writers explicitly and implicitly have always questioned future city making in their time. Some famous examples can be found in contemporary history. For instance, American urbanist Jane Jacobs (1961) argued that modern urban planning principles served planners' utopian interests which ignore the actual working of cities. In her monumental book: *The death and life of Great American Cities,* she attacked modern orthodox urban planning and rebuilding principles. In the 1990s, sociologist Saskia Sassen (1994) analysed the global city phenomenon and argued that economic globalisation generates inequality among cities on a global scale and within cities themselves. Frederic Jameson (2003) attacked the consumerism aspect of contemporary future city making. He argued that modern cities' development lacks imagination, because they continue to create what Rem Koolhass calls 'Junk Space'. Following Henri Lefebvre (1991), David Harvey (2012) argued that the nature of urban development is a process of capital accumulation. In response to this capital accumulation process, he argued that there is a 'right to city'. It is a collective right for people to transform the city from a site of capital accumulation to a place where the public can debate over what power is doing.

The 'smart cities' movement is still in its infant stage. We can read and hear about many smart city initiatives in the media coverage. However, most of those initiatives are merely visions or remain in the experimental stage. Nevertheless, scholars have conducted many conceptual critiques of those visions. Robert Holland is one of the earlier smart city critics. Right after IBM launched its Smart Planet vision[3] (2008), he examined IBM's vision alongside many self-designated smart city initiatives and found that most of these smart cities visions were driven by big businesses or multi-national technology companies. Drawing on Harvey's (1989) 'entrepreneurial city' and Peck and Tickell's (2002) 'neo-

[3] http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/smarterplanet/

liberalizing space', Holland argues that many of those smart cities visions are self-imposed market devices for city branding and function as an excuse for entrepreneurial urbanism (Holland, 2014). Rob Kitchin is another 'smart cities' critic. He (Kitchin, 2015: 133) compares current 'smart cities' ideas with other future city ideas that have arisen in recent years, including the competitive city, creative city, sustainable city, green city, and resilient city. He argues that the 'smart city' is a technological version of those new city visions. The potential problems of 'smart cities' are similar to the other new city visions, such as urban gentrification, widening inequality, and social polarisation. He warns us that a neo-liberal urban utopian ideology is on the rise and that those utopian visions of smart cities lack concern for democratic decision making, citizen participation, and alternative thinking in making their future cities (Ibid). More and more critics (Vanolo, 2013; Townsend, 2013; and Greenfield, 2013) follow Holland and Kitchin's arguments, and point out that the current 'smart cities' idea is becoming a technology giants' 'privatopia' (Vanolo, 2013). Their visions of 'smart cities' pay more attention to selling technologies, rather than focusing on people (Greenfield, 2013; Townsend, 2013: 118).

In opposition to the top-down smart city idea driven by technology companies, there are emerging discourses on bottom-up citizen centred urban innovation. This approach explores different ways of harnessing technologies at a grass roots level (Hemment and Townsend, 2013; Townsend, 2013). Under the big umbrella of bottom-up approaches to smart cities, many citizens driving smart city ideas have emerged in recent years, such as the 'smart citizen', 'civic hack', and 'citizen sensing' (Saunders and Baeck, 2015). However, the citizen driven smart city approach is also questioned by many scholars. For instance, following Osborne and Rose (1999), Vanolo (2013) regards the idea of the 'smart citizen' as an instrument for 'government at a distance'. He argues that the idea of 'smartness' is becoming a field of social control. Gabrys (2014) shares a very similar view with Vanolo, but she goes beyond 'social control' and argues that the computational materialisations in cities help to distribute power through urban spaces and processes. In order to understand the actual roles for 'citizens' and 'the people' in smart cities, Cowley, Joss and Dayot compared six UK smart cities and proposed four modalities of publicness, namely, 'service-user', 'entrepreneurial', 'political', and 'civic' (Cowley et al., 2017).

Apart from criticisms of top-down and bottom-up smart city visions, some researchers focus on the impacts of embedding certain technologies into the urban fabric. For example, Kitchin

(2013) explores the relationship between real-time data and the city. He identifies three potential issues that real-time data might bring to urban development. First, he argues that technocratic governance is a reductionist and functionalist approach to the city. There are wider city elements that data do not take into account. Therefore, there are deep structural problems that cannot be solved simply by improving efficiency. Second, the one size fits all smart city idea generated by technology companies does not efficiently respond to the uniqueness of a place. Third, the combination of big data and data centre might bring many oligopticon systems together into a single panoptic vantage point. There is concern about the level of surveillance that big data might bring to societies (Kitchin, 2013). There are other general critiques about smart city solutions. For example, Michiel de Lange and Martijn de Waal point out that location-based services and customer loyalty cards will transform urban areas into spaces that produce and practice 'social sorting' (Lange and Waal, 2013; Crang and Graham, 2007). Vestergaard et al., (2016) argue that the proposed 'smart city' infrastructure visions reduce humans to objects and input devices that can be measured. It might disempower people rather than empower them. They use intelligent street lighting as an example to support this argument. They argue that humans use visual information to make the decision whether to risk a walk in the darkness or not of an evening. This type of decision making would no longer be possible in a condition of intelligent street lightning where a street may look dark from a distance even though when people approach it the light will automatically switch on. They suggest that intelligent street lighting might be an energy efficiency solution at night time, but it interferes with our human decision-making processes.

2.3.2 The empirical turn in 'Smart Cities' research

The conceptual criticisms of 'smart cities' are ongoing. However, the general critiques of 'smart cities' visions are challenged by viewing 'smart cities' as universal, rational, depoliticised, and operating toward profit maximising and the interests of multi-national companies (Shelton et al., 2014). This one-size fits all smart city narrative dominates current academic accounts. But how the 'smart cities' concept operates in a real local context is more diverse and messy. So, smart cities research has entered into a new phase (Cowley et al., 2017). As Kitchin (2015) suggests there is a need to have more in-depth empirical studies about specific local smart city initiatives. For example, how is the 'smart city' adapted in a local context? How are initiatives constructed and adapted from arguments elsewhere? How is the smart city initiative implemented in reality and how does reality respond to it? To what extent are the initiatives creating inequalities in the city? Shelton et al. (2014) share a similar attitude with Kitchin, they point out that the idealised visions of smart cities dominate the social imaginary of future cities. They urge us instead of critiquing these unrealistic visions, to study the *"actually existing smart city"*. To understand the actual process of how a particular smart city paradigm becomes grounded in a particular place.

In the past few years, there have been some empirical case studies on 'smart cities'. For example, Datta (2015) investigated the 'entrepreneurial urbanisation' in Dholera (India) and argued that Dholera's smart city project prioritises urbanisation as a business model rather than a social justice model. Halpern et al., (2013) investigated the Songdo smart city (South Korea) and pointed out that test-bed urbanism is an epistemology which facilities a specific way of knowing. A digitally mediated city life will influence the way people experience urban reality. In the Songdo vision of the future city, the future mirrors the past because it relies on past data to predict the future. Gaffney and Robertson (2016) used smart city systems in Rio de Janeiro as a case study and found out that the "smartness" in Rio lacks citizen participation and citizens input in decision making. As a result, Rio's smart city only represents a narrow set of economic and political interests.

These empirical studies on smart cities seem to mirror the smart city criticisms identified above. However, most of these empirical smart city cases are chosen from the global south or are often cities built from scratch. There is a need to understand how 'smart city' ideas are taken and developed in more mature cities and in the global north (Shelton et al., 2014). Following this line of inquiry, empirical studies about the implementation of 'smart city' strategies at a European level have blossomed in the past few years (March and Ribera-Fumaz, 2014). For example, Crivello (2014) studied the circulation and implementation of the 'smart city' idea in Turin (Italy). He focuses on studying the actors, processes, and networking that were involved in accepting and implementing smart city ideas in Turin. The research found that the idea of the smart city in Turin was coming from the European Union and the adaptation of the smart city idea was actually a re-labelling of existing initiatives in the city. March and Ribera-Fumaz's (2014) research looks at the implementation of 'smart city' ideas in Barcelona. They identified the contradictions of implementing 'smart city' ideas in Barcelona. They urge more detailed research about how cities become a "*laboratory for capital*" and whether it is inclusive for citizens or not? Thomas et al., (2016) take a rather unique approach. Instead of studying how a smart city vision is contested in a local context, they explore citizens' visions of future cities in three UK cities (London, Manchester, and Glasgow). Their research provides some valuable insights about local citizens' expectations of the future city and this is an aspect that has often been neglected in much smart city research.

2.4 Research gaps and foreshadowed questions

2.4.1 Research gaps in current 'Smart Cities' literature

This research is built upon current 'smart cities' literature. It is aware of the criticisms of 'smart cities'. It is also in line with the empirical turn in 'smart cities' research and would like to contribute to this line of inquiry. It seeks to address the gap caused by the lack of in-depth empirical research in the current 'smart cities' literature. As we can see above, most current 'smart cities' empirical research relies heavily on data collected from documents and interviews. As a result, there is still a lack of substantive insights about the technological, social, and political processes that are involved in the emergence and realisation of a specific smart city initiative. This research addresses this gap through detailed empirical research into the innovation process of a smart city project. It relies not only on data from documents and interviews, but also from the researcher's ongoing participation in a specific smart city innovation process.

While studying the innovation process of a particular smart city in the making, this research also addresses another two gaps in current smart city literature. One gap is the lack of understanding about the role of vision in the innovation process. Vision clearly has a role to play in the current 'smart cities' movement. As noted above, most 'smart cities' nowadays remain at the vision stage. Much 'smart cities' research holds a dualist attitude towards visions. They either treat vision as an object to study, or research what happened in reality. This reflects the assumption that a vision is a static and external factor, independent from the innovation process. Using this assumption of vision, researchers often ask questions, such as, who produced the visions? How could the vision have been made differently? Or, what is wrong with the vision? As a result, the research mainly focuses on examining the content of a smart city vision or conducting a reality check (including citizen's expectations of future cities) against the proposed visions. This way of thinking about vision blinds them from looking at what visions actually do in an innovation process. So, this research would like to address this gap. It starts with an assumption that vision is neither static or an external factor independent from the social-technical innovation process. Instead, vision is a fluid factor which is embedded in the innovation process and co-exists with other visions or expectations. So, instead of critiquing the content of a 'smart cities' vision or simply observing what materialised vision actually does in reality, this research will explore the role that vision plays in a particular smart city innovation process.

Apart from the role of vision, another gap I would like to address is citizen participation and the challenges of an actual smart city project. From the conceptual criticism of 'smart cities' discussed above, we already know that there is a lack of bottom-up citizen led smart city movements. Some empirical research also shows that there is a lack of citizen participation in current smart city making. However, we need to have a deeper understanding of citizen participation at a project level. For example, where is the opportunity for citizens to participate in a project? To what extent are citizens involved or not involved in a particular smart city project? What are the challenges of engaging citizens? Through following a smart city innovation process, this research seeks to investigate the issues of citizen participation in detail.

2.4.2 Foreshadowed research questions

In response to the three research gaps that I identified in the current 'smart cities' literature, I formed the following three foreshadowed research questions to guide the exploration of this research.

(1) *What are the innovation processes of a smart city project?*
(2) *How does the vision contribute to the innovation processes of a smart city?*
(3) *How are citizens imagined and enrolled in the processes?*

The first research question responds to the first research gap which aims to gain a more detailed understanding of the innovation process of a specific smart city project, for example how does a smart city project emerge or adapt in a local context? Who are the main actors of the project? How is it implemented in a local context? The second research question resonates with the second research gap, which seeks to understand the role of vision in the innovation process. Vision in this context mainly refers to the specific smart city vision that

I am going to investigate. However, I will also pay attention to other collective and private visions and expectations that I have encountered in the smart city innovation process. The last question responds to the third research gap in the literature. It seeks to understand more about the possibilities of citizen participation in a smart city project.

2.5 Conclusion

This chapter locates this research in the broader context of the ‘smart cities’ phenomenon. It identifies three gaps in current smart cities research that this thesis will contribute to. These are the innovation process, the role of vision, and citizen participation. In the following chapter (Chapter 3), I will talk further about how the research was carried out in order to address the three gaps. Within the chapter, I will also briefly address the process of selecting and assembling a theoretical framework to investigate the three questions. A detailed review of the theoretical framework will be presented in Chapter 4.

Chapter 3

Methodology

This chapter aims to introduce the design and research methods of this study. It starts by providing the rationale of choosing an ethnographic approach as a vehicle to explore a smart city in the making. It then explains the reason for choosing smart city project OPHC as a case for this research and the process of sampling sites, events and people within the case of OPHC. This is followed by introducing the methods of data collection, the process of data management and data analysis. It also illustrates the *iterative-inductive* (O'Reilly, 2005) process of configuring a theoretical framework to interpret data and describes the various stages of data analysis. Finally, this chapter addresses the ethical considerations of this research and reflects on the researcher's own role in relation to the research.

3.1 The initial approach

3.1.1 The philosophical assumptions of this research

I would like to start by clarifying the philosophical assumptions of this research because the choice of philosophic assumptions influences the way researchers find data to answer the research questions (Creswell, 2013). The philosophical assumptions refer to questions about 'ontology' (the nature of reality) and 'epistemology' (the nature of knowledge). Creswell (2014) calls this set of philosophical beliefs 'worldviews', while Mertens (2010) calls them 'paradigms'. There are many different 'worldviews' and 'paradigms', such as positivism, post-positivism, social-constructivism, critical inquiry, feminism, and postmodernism (Crotty, 1998). Due to the word limit of this research, I do not go into detail about each 'worldview' in this chapter and only address the one that is most suitable for this research.

Among the many philosophical assumptions, I chose the social constructivism worldview (often combined with interpretivism) for this research (Creswell, 2014). Social constructivism proposes that "*individuals seek understanding of the world in which they live and work. Individuals develop subjective meaning of their experiences - meanings directed toward certain objects or things*" (Ibid: 8). The 'ontology' of this philosophical position is that reality is socially constructed through lived experiences and interactions with others (Mertens, 2015). There can be multiple realities. For example, one phenomenon might mean different things to different people. So, people's mental constructions might be in conflict with each other. Also, the perception of reality may change throughout the process of the research. The 'epistemology' of this approach requires a more interactive mode of data collection whereby researchers and participants interlock and influence each other. Constructivists regards subjective meaning as something negotiated socially and historically (Creswell, 2014: 8). Meanings are not bounded to the individual, but are formed through interactions. Therefore, researchers have to acknowledge that they are part of interactions and realise that their background also shapes the way they interpret the data.

Social constructivism is the most suitable philosophical assumption for this research because the research aims to study the innovation process of a smart city in detail. The 'smart city' is a worldwide emerging phenomenon but different people have different ideas about what a 'smart city' is. So, there are multiple realities about the 'smart cities' phenomenon. Also, people have constructed the idea of 'smart cities' through interaction with each other. This means that to study the 'smart cities' phenomenon and its innovation process in a local context requires the researcher to focus on people's smart city meaning making activities. This includes observing individuals' processes of interaction, their expressions, and how I, as a researcher, make sense of it through interacting with them. It is worth noting that I also want to explore the question *How are citizens imagined and enrolled in the processes?* The results of this research might reveal who participates and who does not participate in the innovation process. This might indicate whether change is needed. So, this research might look like it adopts a critical or transformative worldview. However, I would like to argue this is a by-product of this research and not the main intention of this research.

3.1.2 The ethnographic approach

Using the social-constructivism approach, we know that reality can be accessed through interactions between the researcher and participants. So, qualitative methods such as observation, interview, and analysis of texts tend to be used in this research 'paradigm' (Mertens, 2015). There are several approaches in qualitative research, such as narrative research, phenomenological research, grounded theory, ethnography, and case studies (Creswell, 2014). Different approaches have different methodologies and research designs which guide researchers to choose the research methods (Crotty, 1998).

This research seeks to understand the innovation process of a specific smart city innovation. This involves understanding a group of people's (smart cities innovators) collective meaning making with regards to 'smart cities'. Thus, it does not focus on studying a specific individual (narrative study) or an individual experience (phenomenological research) of 'smart cities'. It also does not aim to build a theory for 'smart cities', so grounded theory is not suitable for this research either. Ethnographic research and case studies are both possible approaches for this research. The former focuses on the interpretation of a cultural, social group, or a system. It often looks at people's interactions in ordinary settings, such as what they do (behaviour), what they say (language), the tensions between what they do and what they say, and what they make and use (artefacts). What an ethnographer tends to do in this approach it to distil patterns such as life cycles, events, and cultural themes from the setting. In terms of the research process, ethnographic research often involves ethnographers immersing themselves in people's daily lives and using participant observation to collect data. They also conduct interviews with members of groups and gather artefacts in the process. Case studies meanwhile are usually applied to explore a bounded system or a case (or multiple cases) in detail. Multiple data resources are often collected to shed light on a specific case, for example, interviews, observations, audio-visual material, and documents.

There are overlaps between ethnographic research and case studies. For example, both approaches focus on exploring processes and details. They also apply similar data collection methods (Creswell, 1998). Ethnographic research always ends up in a case as well. Researchers have attempted to make distinctions between ethnographic research and case studies. Parker-Jenkins (2016) argues that the key difference between ethnographic research and case study is the level of "immersion". Ethnographers often immerse themselves in the context and generate a large set of data. Traditionally, an ethnographer tends to spend their time constantly in the field to build up relationships of trust with people, and this can last for years. However, due to the impact of technology and shortening contracts for researchers employed by specific programmes, modern ethnographic research is more likely to "*last months rather than years*" (Hammersley, 2006). However, this still involves fairly lengthy contact. Case study research does not necessarily need constant immersion and it may only last hours, days, or weeks. Hammersley (2006) also highlights another distinction between ethnographic research and case study research; although both approaches share similar data collection methods, a case study can only rely on the method of interview to fulfil the research purpose, whereas ethnographic research does not exclusively rely on interview and often involves the use of participant observation to collect data.

Creswell (1998) suggests researchers ask themselves several questions before choosing an approach. For example, what approach is frequently used in the given field? What kind of training do the researchers have? What is most needed to contribute to the scholarly literature in the field? Which approach is the researcher more comfortable with (e.g. a more structured approach or a more storytelling approach) (Creswell, 1998). Bearing these questions in mind, I think an ethnographic approach is most suitable for this research. There are two main reasons. One reason is that a smart city innovation is very much about a technological innovation. The ethnographic approach is particularly relevant to study science and technological innovation at the micro level (Barry, 2001; Latour and Woolgar, 1986; Hess, 2001; Rabinow, 1996). According to Hess (2001), there are at least two generations of researchers using the ethnographic approach in the interdisciplinary field, Science and Technology Studies (STS). So, it is a sort of tradition to use an ethnographic approach to study the process of technological innovation. Another reason is that there is a need for a more detailed empirical study about smart city making. As I identified in Chapter 2 many current smart city literatures rely heavily on interviews and documents to understand the smart city phenomena. In order to generate a much richer picture of smart city making, the ethnographic approach is required, because it not only relies on conventional methods (e.g. interview and documentary sources), but also requires researchers to immerse themselves in the smart city making process and conduct participant observation. Based on these two factors, I chose an ethnographic approach for this study. Like all approaches there are advantages and shortcomings; the ethnographic approach is also faced with many charges, such as, the crisis of representation and the relationship between ethnography and theory. I will address both issues later (see section 3.4 and section 3.6).

3.2 Sampling

3.2.1 Selecting a smart city project

In order to fulfil the objectives of this research, the first thing to do was identify a suitable city undertaking a smart city project. There is no a standard way to select an ethnographic setting/case. However, several factors tend to affect the selection process. First, theories or literatures that ethnographers read often become the starting point for them to select an ethnographic setting/case. Although ethnographers might not have hypotheses to test, they still cannot escape the influence of the theories/literature that they read. As O'Reilly (2005) points out, it is impossible to start ethnographic work without preconceptions. Second, researchers can choose a setting based on well-defined research problems or what Malinowski (1922) referred to as 'foreshadowed problems' (Hammersley and Atkinson, 2007: 21). Although researchers usually find their 'foreshadowed problems' are not open for investigation in their chosen setting/case, those initial problems still have the capacity to influence the selection of the ethnographic setting/case at the beginning. Third, a setting/case may be selected based on an opportunity that arises that seems worth investigating. For example, a researcher might encounter a historical event in the making that is yearning for his/her attention. Moreover, pragmatic factors, such as easy access, travel costs, geographical location, cannot be neglected in choosing an ethnographic setting/case. In fact, it is often the major consideration for researchers and is the reason why researchers often narrow down the selection to places close to where they live. As Hammersley and Atkinson (2007: 31) point out "*usually ethnographers study only one or small number of settings, and sometimes there are ones that are geographically close to where they are based. Often this is forced by the cost of using more remote sites and the limited resource available*". Choosing a local smart city project for this research was influenced by all the factors mentioned above, but they came in a different order in shaping the sampling decisions.

(1) Exploring the possibilities of conducting research in Harbour City

I needed to identify a suitable city to conduct this ethnographic research. Taking the three 'foreshadowed problems' and practical reasons (e.g. research timeframe and travel fund) into account, I decided to explore the possibilities of conducting this research in the city where I was based, Bristol, a middle-sized city located in England (UK). The choice of Bristol was not merely because it was convenient. I had noticed that Bristol could make an interesting case study because of its recent claims to a specific commitment to future city making. In this thesis, I give Bristol a pseudonym. I call it Harbour City. The reason for this is because this research aims to study the smart city phenomenon in a real context rather than the city itself. So, using a pseudonym aims to help me to maintain a certain distance from the city itself and concentrate on slicing out the smart city making process. I will address the ethical considerations of this choice further in the ethics section below (See page 61).

In order to explore the possibility of carrying out this research in Harbour City, I conducted several informal interviews and field trips to Harbour City in February 2015. The selection of interviewees and places to visit were based on the criteria that they were 'insiders' of Harbour City's future city making. With the kind introduction of my supervisor Professor Keri Facer, I managed to contact five people in Harbour City who come from various local institutions, such as a local university, a social enterprise organisation, and a community organisation. Their knowledge covers the areas of digital technology, citizen engagement, aging and wellbeing, environment and green technology, civil engineering, and local minority groups. This initial mapping made me realise two things. First, Harbour City has various future city visions, such as green city, smart city, resilient city, happy city, digital fun city, all-age-friendly city (Facer, Horner, and Manchester, 2014), future transportation project, tele-health initiative, and many others. Second, amongst those future city visions, there was a newly launched smart city project in Harbour City which I have given the pseudonym, Open Programmable Harbour City (OPHC). During interviews, three out of five participants mentioned OPHC. The smart city project OPHC immediately drew my attention and I considered it as a possible case for my research objective.

(2) Choosing Open Programmable Harbour City (OPHC) as the ethnographic case

To deepen my understanding of OPHC, I started to read the information available about OPHC online. I also applied the snowball method to talk to more people in Harbour City who knew something about OPHC, including local civil servants, engineers from the Harbour City University, and some local businessmen. The piece-by-piece information I pulled together about OPHC showed that OPHC would make a suitable case for the purposes of this research. One reason for this was that OPHC offered a good opportunity for me to answer the three foreshowed questions. OPHC officially launched two months before I narrowed the research focus to Harbour City (March 2015). I was lucky to be in the right place at the right time. The entry time allowed me to follow and witness a real-time smart city innovation process. Alongside following the innovation process, I could observe the role of vision and citizens in the innovation process.

Another reason for choosing OPHC was because the vison of OPHC demonstrated a unique smart city project which deserved attention. It is a joint venture project between the local council and the local university. Technologically speaking, it has not only installed some conventional smart cities technologies (e.g. Internet of Things and smart applications), but has also adopted a state-of-art networking technology Software Defined Network (SDN). This technological configuration claims to bring transitional capacity to the existing network regime and the way a city network operates. Socially speaking, OPHC was aware of the problems of top-down smart city innovation models and lack of citizen engagement. It proposed to build a smart city project that allocated roles for different people. It also specifically put citizen at the centre of its vision. For instance, it wanted to open its programmable infrastructure for anyone to test their applications. It also proposed several citizen engagement elements in its vision. Both its technological configuration and citizen engagement agenda suggested that OPHC would be an interesting case to investigate and might enrich our understanding of the smart city phenomenon.

3.2.2 Sampling sites and people within the case

The selection of a local smart city project was not the only form of sampling that was involved in this research. A researcher cannot be everywhere all the time. She or he needs to constantly make decisions about where and when to observe, and who to talk to (Hennink et al., 2011; Hammersley and Atkinson, 2007). So, I also needed to sample within the case of OPHC. This sampling process mainly referred to two things: where I would conduct participant observation and who I would interview. Below, I provide readers with an overview of the two sampling processes. It is worth noting that the sampling process was not as tidy as I present it here. The number of events I attended and people I talked to were more than I describe below. The full list of key events and interviews can be found in appendix 1.

(1) Samplings sites

Identifying suitable sites for research is not straightforward. Researchers often know very little about the field and they invest a lot of time and energy getting to grips with the sites they have chosen in the early stages of fieldwork (O'Reilly, 2005: 38). Thompson (1988) regards this exploring process as the 'general gathering stage'. O'Reilly (2005: 38) vividly describes this stage as, *"putting your toe in the water to test it before plunging in*". Similarly, Fetterman (1998: 32) talks of a 'big-net' approach in the early stages of ethnographic research. In this stage, ethnographers tend to mingle with everyone that they can and attend a wide range of events. The process helps ethnographers to capture a big picture of the case, refine their focus, and narrow down the research to specific sites and people. In order to find sites to observe, I went through a 'general gathering stage' between May 2015 and July 2015. I reviewed news, documents and reports online about OPHC. The documentation process provided me with a better idea about OPHC and of the events to attend. I also interviewed the Chief Technology Designer of OPHC (Susan) and some engineers from the NEXT Lab. The interviews helped me to build a basic understanding of the use of technologies in OPHC. I also actively attended a whole range of events, including *a workshop for OPHC's application Data Dome*, a *social scientists' gathering event*, and *Harbour City to Delta City webinar 1*. Those events established the foundation of the fieldwork for this research. After three months' exploration, I noticed that it was difficult to find a single site to conduct observation because the innovation activities of OPHC happened in multiple sites, including relevant projects, conferences, workshops, festivals, etc. The nature of the ethnographic context of this research might resonate with some contemporary understandings of the ethnographic field, such as 'multi-site ethnography' (Marcus, 1986; Hannerz, 2003) or 'field-event configuring' (Delgado and Cruz, 2014: 44) in organisation ethnography (Sim, 2017: 26). In response to the fluid, composite, and distributed nature of the ethnographic field of this research, I sort the OPHC related events into four types: (a) Events irrelevant to OPHC. (b) Events irrelevant to OPHC, but that could deepen my overall understanding about OPHC. (c) Events related to OPHC and has a series of planned events. (d) Stand-alone events which related to a specific theme of OPHC (**Figure 1**).

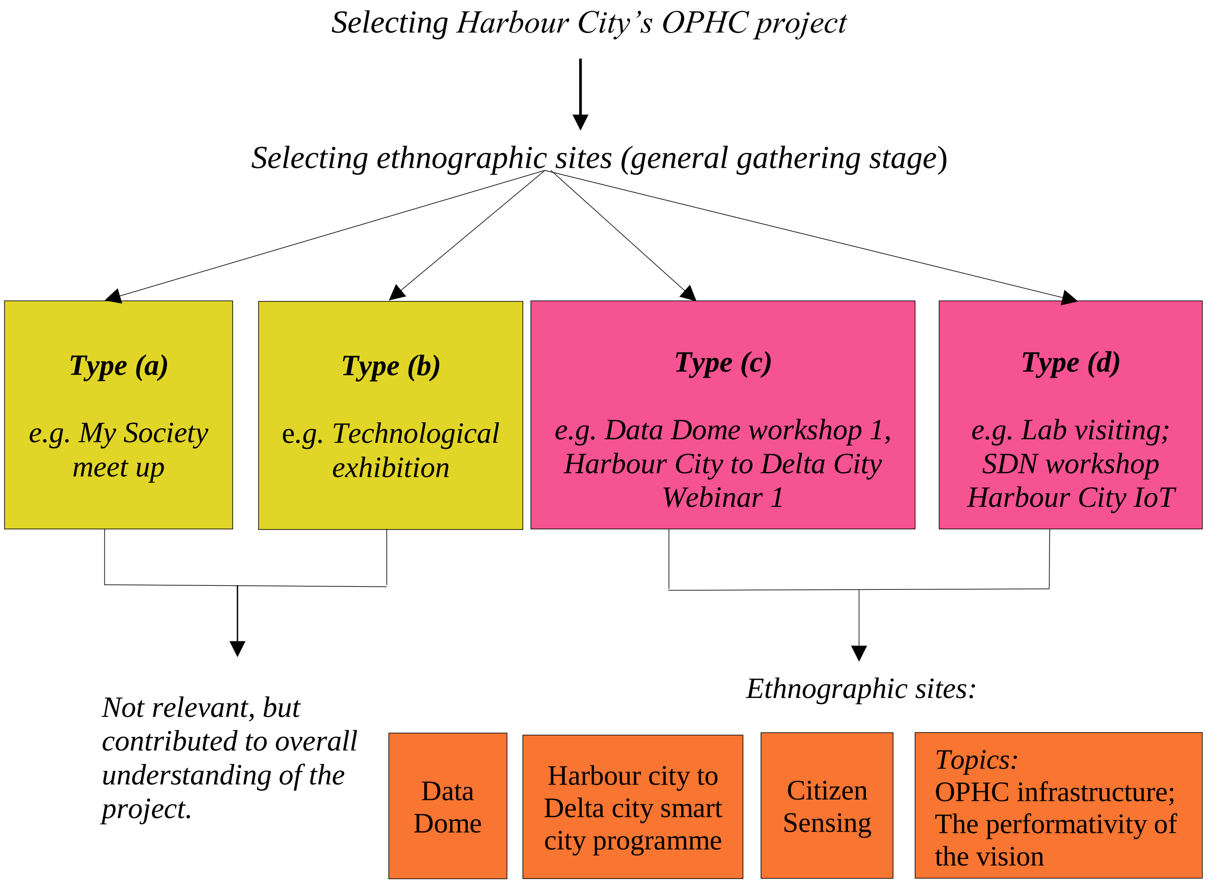


Figure 1. *The processes of selecting the ethnographic sites*

Type (a) events were irrelevant to OPHC. An example of this type of event was *My Society meet up*. According to the description of the event, the Chief Manager of OPHC (Chris) and the Chief Technology Designer of OPHC (Susan) were scheduled to give a talk but they did not turn up so, what I observed in this event was not relevant to OPHC at all. Type (b) events were also not related to OPHC, but had potential to enrich my overall understanding of OPHC. I will come back to this point later.

Type (c) and type (d) events were considered as ethnographic sites for this research. Type (c) events were directly related to the innovation process of OPHC. They were a series of events associated with OPHC. In the 'general gathering stage', I identified two type (c) events. One was the experiment of building OPHC's first application, *Data Dome*[4]. Another

[4] This is the first application of OPHC and it aims to become an urban data visualisation device to visualise data that collected from the OPHC infrastructure. More on the Data Dome in Chapter 6.

one was the *Harbour City to Delta City smart city programme*[5]. The former allowed me to conduct a detailed observation into the implementation of the vision of OPHC, while the latter showed a very interesting phenomenon in the innovation process, that of innovation diffusion. Type (d) events were different, stand-alone events, that related to some aspect of OPHC. For example, *OPHC infrastructure* was a topic found in several independent events, including the *SDN workshop* and *OPHC Tech meet up.* Those events were not related to each other, but together they revealed the innovation process of the OPHC infrastructure.

After the 'general gathering stage', I formed some ideas about where to go. I closely followed two type (c) events: *The Data Dome application* and *the Harbour City to Delta City smart city programme*. In the process, another type (c) event emerged; a *Citizen Sensing project*[6] led by OPHC's local host partner Straw House. The project was considered relevant to OPHC because it was supposed to co-produce an OPHC application with citizens. So, I decided to include the *Citizen Sensing project* in my sampling of ethnographic sites. I also attended some type (d) events. Key themes that emerged in the process not only drew on the infrastructure aspect of OPHC, but also covered other aspects of OPHC, such as *the performative roles of the OPHC*.

The type (c) and type (d) events are the major sites for this ethnographic research. But the type (a) and (b) events also contributed to this research. For example, they deepened my understanding of the technological components of OPHC and helped me better understand the context (Harbour City). I also met some important actors of OPHC at some of those events, for example, I attended an event about data and healthcare, where I was looking for information on the OPHC related tele-health application, but though the event turned out not to be relevant, I met John who later helped Straw House to develop a sensing application (Toad) (See Chapter 6). Having met John at this event made it easier to ask him for an interview at a Citizen Sensing event later on.

The sites that I gradually selected in the process covered many aspects of OPHC, but I should admit that it is not the complete picture of OPHC. It is impossible for one researcher to

[5] This is a smart city communication programme between Harbour City and Delta City. OPHC seek to diffuse to Delta City through this programme. More on the diffusion process in Chapter 7.

[6] This project aims to co-produce a sensing application with citizens, and this application seeks to use OPHC infrastructure. More detail in Chapter 6.

follow the entire process of a large-scale project like OPHC. As Hammersley and Atkinson (2007) remind us, in selecting ethnographic sites, a researcher must always make a trade-off between breadth and depth of investigation because the more settings studied the less time can be spent in each. In choosing a suitable site for study, I was aware of other sites of potential interest that I could not include. For example, there was an Engineering Professor from Harbour City University who planned to do something with the OPHC infrastructure. But, I only found out about this at the very late stage in my data collection, so I decided not to include it. When choosing where to go, I also had to take into account the ethical concerns of real-time research. This research follows a real-time smart city innovation process which gained ethical consensus from many innovators. Although I was welcomed to observe the process and sometimes even invited to events. I made the choice not to request to observe some events and to maintain a good distance at other times. This is because I considered my presence at certain events might impact the innovation process and I also did not want to put pressure on the innovators. However, I made sure to balance ethical considerations with the need to gain enough data. My knowledge and cultural background also influenced the way I selected the site. For example, OPHC has many interactions with cities overseas, including Delta City in China and Windy City in the USA. There are many reasons that I chose Delta City rather than Windy City. Apart from the fact that I heard about Delta City earlier than Windy city, there was also a concrete project plan between Harbour City and Delta City for me to conduct a series of observations. Moreover, my personal background also influenced my selection of Delta City because I had lived in the region for four years and had thus built up some understanding of Delta City's culture and industry. This personal background gave me greater confidence in understanding the interactions between Harbour City and Delta City.

(2) Sampling people

Apart from selecting where to go, I also needed to select the people to talk to. This mainly included choosing people with whom to conduct informal interviews and arranging formal interviews with others. I would like to briefly talk about how I selected the respondents for both types of interviews.

I used two ways of sampling people for informal interview: my judgement and sheer good fortune. The majority of the time, I approached people for informal interviews based on my judgement that each person was important to talk to. For example, based on this type of hunch, I interviewed a game designer in the site of the *Data Dome*; Chinese participants in the site of the *Harbour City to Delta City smart city programme*; a project manager of *Citizen Sensing*, and a community activist, among others. Sometimes, I was lucky enough to meet the right person at the right time in the right place. For example, I was interviewing Chris at the DOCK one morning and I noticed the engineering Director of MiniCat (Emma) also at the DOCK. I knew that she was doing something about the Data Dome. After the interview with Chris, I went to say *"hi"* to Emma and asked her about her recent involvement with the *Data Dome*. To my surprise, she had just brought a group of six engineers to work on developments for the dome. From our previous interactions, she already knew that I was doing research about the Data Dome so she immediately asked her engineering team for consent to be interviewed and recruited a group three engineers for me to interview. It was quite unexpected, but in the end, I gained oral consent to conduct the interview from the engineers and promised not to write anything about their design before their official release date. This type of good luck happened many times in my fieldwork.

In terms of finding suitable people for formal interview, I usually applied non-probability sampling. This included 'theoretical sampling', 'judgement sampling' (the researcher selecting the most suitable person based on her knowledge), and the 'snowball technique' (finding one informant from another informant) (Brewer, 2005: 79). I mixed the use of these three sampling strategies to select people with whom to conduct interviews. For example, after the Data Dome launch event, I needed to understand how 'insiders' thoughts about the launch event. Based on my knowledge about the social network in the field, I thought Henry from the Data Dome team might be a suitable person to talk to and I contacted him for interview. In this case, I use 'judgement sampling' to choose the interviewee. Sometimes, I also applied the 'snowball method' to select people to talk to. For example, in order to understand the emergence of OPHC, I interviewed a key informant (Ruby) from Harbour City Council because I knew Ruby was involved in the history and current development of OPHC project. Through Ruby I got to know that Vincent (a computer scientist) and Brian (the Director of the DOCK) were also involved in the history of OPHC. I subsequently interviewed both of them as well. It is worth noting that using the 'snowball method' to find interviewees has a shortcoming; the data can be misleading if too many respondents come from the same group of people, thereby weighting the responses a certain way (Hammersley and Atkinson, 2007: 104). In responding to this drawback, a researcher should maintain leeway to choose who to interview. Thus, when finding people who knew the history of OPHC, beyond contacting interviewees through one person's recommendations, I also identified other interviewees based on my own knowledge and other informants' recommendations.

3.3 Data collection and management

Ethnographic studies tend to use a wide variety of methods to collect data, including participant observation, interview, photography, and documentary (collecting documents and artefacts) (Brewer, 2000: 11). Pink (2009) argues that the choice of data collection methods should consider two factors. First, the method should serve the research questions. Second, it should be a method that best enables the researcher to explore the issue. Taking the two factors into consideration, I used participant observation, interview, photography, and documentary to collect data for this research. For the purpose of clarity, I would like to introduce how I used each method to collect and record data separately. At the end of this section, I will also briefly address how I organised the data that I collected using the different methods.

3.3.1 Participation observation

(1) Using participation observation to collect data

Participant observation is a major data collection method in ethnographic research (Lassiter, 2014: 58). To collect data through participant observation often requires ethnographers to understand aspects of people's life from their own perspectives and from within the context of their own lived experience (O'Reilly, 2005). The data collected via participant observation provides a specific kind of field-based knowledge that touch-and-go surveys alone cannot achieve (Lassiter, 2014). Participant observation is a useful method for this research because it allows for the collection of data about what people say and do to make a smart city, how they interact with each other in the innovation process, and so forth. There are a wide variety of participant observation roles that an ethnographer can take in the field. Gold (1958) classified fours levels of participation in the field: 'complete participant' (researcher completely participates in the event), 'participant-as-observer' (researchers research the field and participates fully in the field), 'observer-as-participant' (participation in the field is limited while the researcher's research identity is at the fore front), and 'complete observer' (researcher completely observes the event) (Brewer, 2000). In this research, I shifted between different participatory roles. Most of the time I took the role of 'participant-as-observer' and 'observer-as-participant'. For example, at the Citizen Sensing site, I took the role of 'participant-as-observer'; I actively participated in the discussions like an ordinary event participant. While, in some less interactive events, such as technological talks, I took the role of 'observer-as-participant'. I listened to what was said in the event and observed how audiences reacted to it. Sometimes, I took a 'complete participant' role. For example, in the *Harbour City to Delta City delegation's visit Day 1*, I helped to translate one official meeting from English to Chinese. In this event, I sat behind one key OPHC actor and translated his words from English into Chinese. In such an intense translating session, my brain was only able to operate in translating mode and could not conduct any initial analysis about what was said. So, I was completely a participant in this event.

(2) Constructing observation data

The observation note is a key way to record data from participant observation. Ethnographers usually have their own style of note taking. I developed a colour coding system at the 'general gathering stage' (See appendix 2). Crang and Cook (2007) suggest observation notes consist of six layers of descriptions including, "location", "space", "others' interaction", "my participation", "reflecting on the research process", and "self-reflections". My observation notes contain the first four elements, while the elements of reflecting on the research process and self-reflection were recorded separately in my research diary and reflexive diary. In recording events, I often started by describing where the event took place, usually followed by sketching the setting in my notebook (**Figure *2***) (More examples in appendix 3). I had to constantly make decisions about what to write and what not to write. O'Reilly (2005: 99) and Emerson et al., (1995) argue that observation notes inevitably reduce events and are highly selective. As I mentioned above, ethnographic work is always a trade-off between breadth of focus and detail (Hammersley and Atkinson, 2007). Although I had some initial idea about what I was interested in, for example, focusing on people's talk and their interactions rather than their body language, I still tended to record whatever I could in the early stages of the fieldwork. As the research went along I developed a clearer focus. The observation notes become more and more specific.

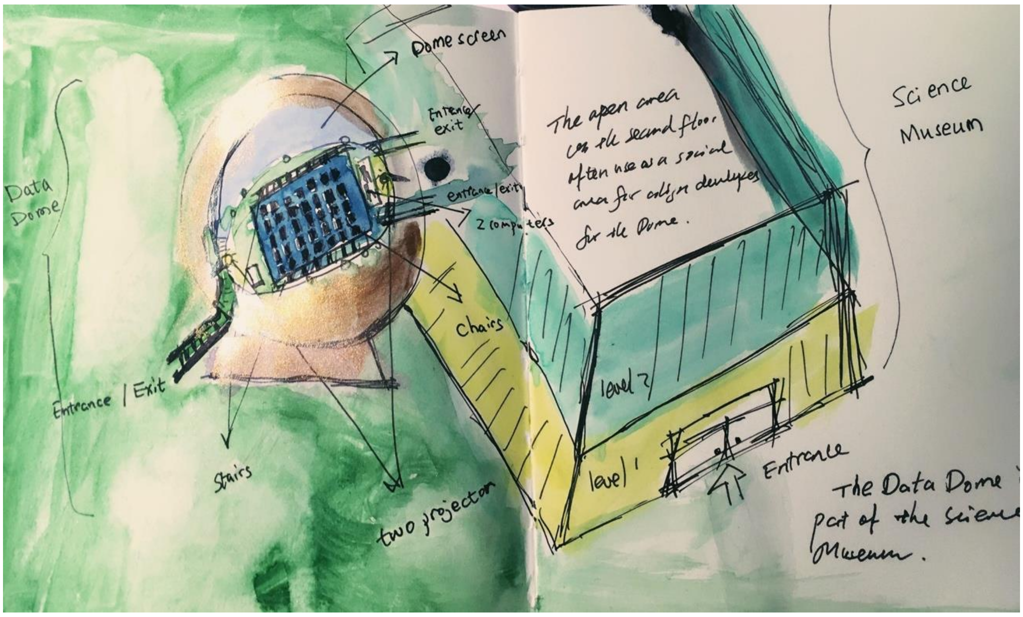


Figure 2. *A sketch of the Data Dome and its relationship with the Science Museum*

3.3.2 Interview

(1) Using interviews to collect data

Interview is another data collection method that is widely used in ethnographic research. Crang and Cook (2007) argue that we should not treat interviews as a separate method because all social research involves learning through conversations. In ethnographic research, the ethnographer inevitably engages in both formal and informal communication. Interview as a data collection method enables researchers to get the subjective views from participants or the insiders' view. Punch (2009) defines interview as "*a very good way of accessing people's perceptions, meanings, definitions of situations, and their constructions of reality*" (Punch, 2009: 144). The use of interview in ethnographic research locates the ethnographer in the larger context of what she/he sees and experiences (Davies, 2008: 40).

As with participant observations, there are also many forms of interview, ranging from a spontaneous informal conversation in the field (informal interview) to a formally arranged meeting (formal interview) (Hammersley and Atkinson, 2007). Informal interviews are like casual conversations and they are the most common interview in ethnographic fieldwork. Ethnographers use these to discover what people think. Whereas, formal interviews often require explicit agendas. They can be formally structured or semi-structured. The formal interview is often used in the middle and late stages of research to collect data on specific questions. Apart from formal and informal interviews, Fetterman (1998) highlights another type of interview called the retrospective interview. It is a type of interview that ethnographers use to "*reconstruct the past, asking informants to recall personal historical information"* (Fetterman, 1998: 40). Retrospective interviews usually contain people's autobiographical descriptions. They tend to be very personal and not completely representative of group. They are valuable because they capture people's perception of the past. This provides a window for the researcher to look at how people's cultural and personal background shape the way they perceive the past (Ibid: 51). Weaving different personal descriptions together, ethnographers can tell the fabric of certain social groups and form an integrated understanding of the target picture.

Each type of interview has its role to play into "soliciting" information (Fetterman, 1998). I used informal interviews, formal semi-structured interview, and retrospective semi-structured interviews in this research. For example, in order to understand the development of the programmable infrastructure, I arranged formal interviews with relevant people, such as the Chief Technology Designer of OPHC (Susan), and engineers from the NEXT lab. I also conducted informal interviews with a member of staff from Light Speed and engineers from the NEXT lab. A full list of key formal and informal interviews is in appendix 1. In general, the informal interviews tended to happen alongside participant observation, while the formal interviews were often arranged after participant observation. There is an advantage to this arrangement. To attend events before an interview allowed me to ask good questions in the interview and the interviewees were more willing to respond to questions with in-depth responses. In terms of interview time, I usually requested one-hour, however, it often took longer than one hour and the longest interview lasted three hours.

(2) Constructing interview data

Informal and formal interviews require different processes to construct and record data. Informal interviews often took place alongside participant observation and sometimes happen accidently. For example, some informal interviews occurred during a chat with participants on the street or in coffee shops. Mental notes and some scribbled key phrases on a piece of paper were the main methods for me to record the data that emerged from this sort of informal interview. In order to retain the information after an informal chat, I normally avoided absorbing new material and immediately sought a place to write down the informal interview based on my memories. If I was lucky enough to meet the same person again after the interview, I would often double check my interpretation.

Collecting data through formal interview requires more procedures and preparations. I chose a semi-structured format for formal interviews, because on the one hand, I had specific questions I wanted to ask participants and on the other hand, I was open to things that emerged from the conversations. To prepare for the interviews, I usually drew up a list of questions that I wanted to ask in the interview (see an example of interview questions in appendix 4). Sometimes, I would also prepare historical documents that might help interviewees to recall things, such as the bid of Gigabit Harbour City. I used a mobile app called Evernote to record the formal interviews. I will address the ethics of recording in section 3.5. The data was stored in the cloud service provided by the application rather than on the smart phone itself. As it turned out this was extremely helpful because I twice dropped my phone in water during the research process. Although I could not turn on my phone due to the water damage, the data was kept safely in the cloud space and could be download to my newly purchased devices. Alongside recording, I also scribbled key phrases in my notebook. Interviewees were allowed to draw on the paper that I prepared. Those drawings helped them to illustrate technological elements or other complex things to me. I post two examples below. **Figure 3** is a drawing done by an engineer. He used the drawings to explain the concept of RF Mesh network and 5G for me. **Figure 4** is a timeline that I co-constructed with a member of the OPHC engineering team in an interview. These notes helped me understand the engineering process of OPHC and the workload of the OPHC engineering team.

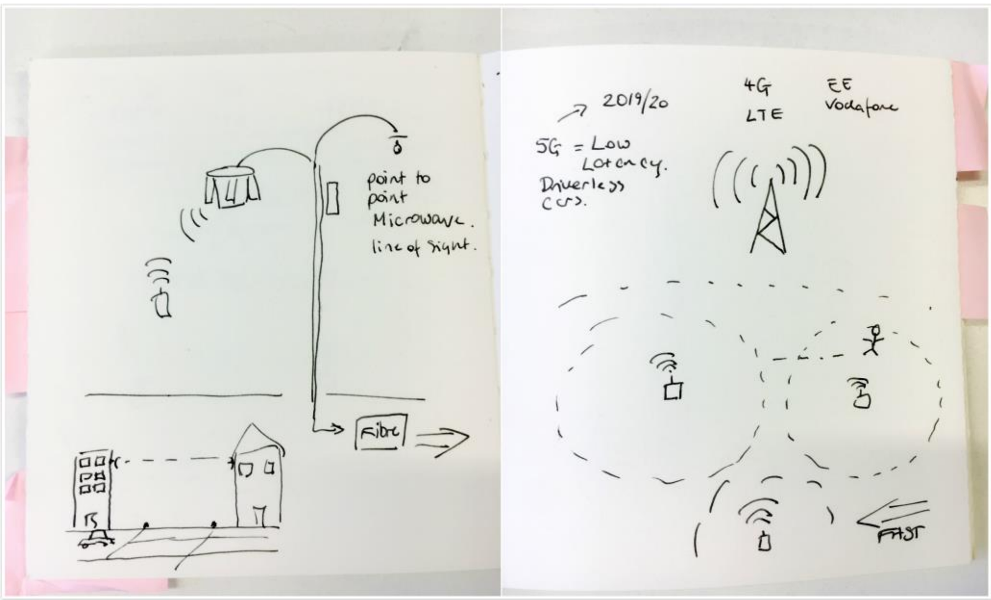


Figure 3. *An engineer's drawing used to explain RF Mesh network(left) and 5G(right)*

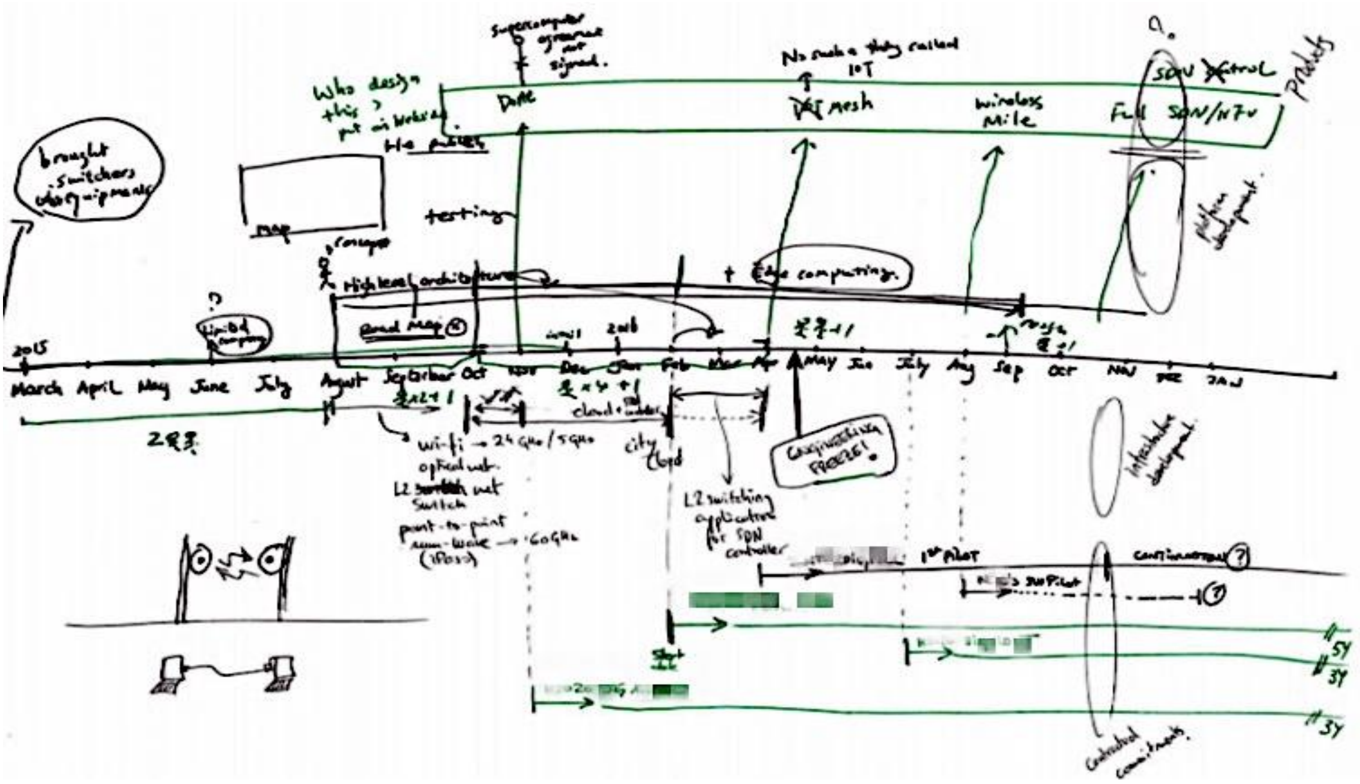


Figure 4. *A member of OPHC engineering team drawing the workload of the OPHC engineering team*

3.3.3 Photography, documentary, and material circumstances/artefacts

Apart from data collected from participant observation and interview, ethnographers easily overlook other types of data, such as photographs, documents, and artefacts (Lassiter, 2014). The empirical data for this research also included those three types of data. Below, I would like to introduce how each method contributed to the data collection for this research.

(1) Photography

Photography always has a role to play in ethnographic work (O’Reilly, 2005). In the early days of the ethnography discipline, there was a positivist attitude towards the use of photos. Photographs are often used as evidence that a researcher was there or that the event had happened. They are deployed in ethnographic research to make arguments more profoundly (O’Reilly, 2005). Apart from functioning as evidence, photos can also be used to show people, places, and objects that are difficult to describe vividly with words. Moreover, photography can serve as an art of ethnographic description. The aesthetic value that photography adds to ethnographic work should be embraced by ethnographers (Crang and Cook, 2007). It is worth noting that photographs present a mediated reality. Some scenes will be chosen in preference to others. But, photographs never intend to show the truth, instead they show a partial truth.

I used a smartphone to take photos at the sites and photos were functional for this research in several ways. First, I used photos as a way of taking fieldnotes. For example, in some fieldwork there were presentation slides which were hard to be note down quickly. So, I used photos to records the slides. Second, I used photography to capture events, activities, and scenes. They helped me to remember what had happened and I also use some photos to support the narrative in this thesis. Readers will come across some of these photos in the empirical chapters. Third, I used photos to record artefacts and physical surroundings that could not be take away from the sites such as the ‘active note’(**Figure 19**) and the Citizen Sensing application ‘Toad’ (**Figure 36**).

(2) Documentary

In the contemporary world, most ethnographic research takes place in a literate society. Therefore, there are always a lot of documents at ethnographic sites (Lassiter, 2014). As Coffey and Atkinson (1996) point out, administrators, accountants, civil servants, managers at all levels, and many other experts are routinely involved in producing, consuming, and circulating written documents such as rule-books, timetables, and memoranda. If we call observation notes, interview transcripts, and photographs first-hand data, then documents can be regarded as the secondary data. There are many types of documents that ethnographers can collect in the process. They can range from informal documents with many copies widely distributed both online and offline to published documents, such as reports.

For this research, I collected both online and offline documents related to OPHC. In terms of online sources, I documented OPHC related news from March 2014 to June 2016. I printed out whatever I read about OPHC online and archived it chronologically in five folders. I also collected documents in the field. For example, at the site of the OPHC programmable infrastructure, I collected documents such as booklets, information sheets from the workshop, and presentation slides. In the end, the documents included OPHC news, official OPHC announcements, presentations slides, advertisements, blogs, bid documents, and conference attendance information. These documents contributed to this research in three main ways. First, they helped me gain an overarching view of the actor-network of OPHC that was not easy to grasp through ethnographic observation. Second, they provided me with information about upcoming OPHC events. Third, they captured events that I could not attend. For example, there were four or five key OPHC actors who frequently travelled around the world to promote OPHC. It was impossible for me to follow them but the online news and reports about these events provided me with a window to see what had happened.

(3) Material circumstances/artefacts

Ethnographic fieldwork not only contains people and documents, but many sorts of "things". The material circumstance of an ethnographic work shapes the performance of an individual and their interaction (Atkinson, 2006). In this research, I paid attention to the physical circumstances of the fieldwork, such as the setting of the site (See appendix 3). I also paid attention to artefacts in the field. For example, at the OPHC infrastructure site, I paid attention to technological components such as the 'active nodes', optical fibre, and the supercomputer (See photos in appendix 5). At the Data Dome site, I paid attention to the chairs, projectors, and other artefacts (see **Figure 2**). At the Harbour City to Delta City communication site, I observed the digital conference system. At the Citizen Sensing site, I paid attention to the artefact, the Toad (**Figure 36**). I was able to take away some of the artefacts, such as a balloon pictured bellow (**Figure 5**), but that was not the case with physical settings and most of the artefacts. In these cases, I use photography and drawing to capture the settings and objects (See some photos in Chapter 5, Chapter 6, and appendix 3).

Figure 5. *A Hello-Kitty balloon I collected at a Data Dome event*

The decision to stop collecting data is often based on several criteria. There are three main factors that influenced my decision to stop collecting data. The first was practical, that is time and funding. PhD's have a specific deadline and a large amount of time is spent on analysis, writing, and editing. So, I could not collect data forever. Second, I stopped collecting data when a project finished its full circle. For example, both the *Delta City to Harbour City programme* and the *Citizen Sensing* project finished within the observation period. I witnessed the whole process of these two projects. Third, I realised that general pictures and patterns appeared again and again in some sites. This was an indication that I should wrap things. For example, at the Data Dome site, the way actors repeatedly aligned game producers and did not realise that the real problems repeated many times. There was no fundamental difference to be found during the observation period.

3.3.4 Data management

At the end of this section I would like to briefly address data management. Data management is an important step in ethnographic research because good data organisation makes ethnographic analysis and writing more effective (Davies, 2008: 10). I formed the habit of organising data after each piece of fieldwork. I built folders in my research computer labelled with a series number and the name of the fieldwork (e.g. participant observation or formal interview). I transcribed some of the important notes (e.g. actors' speeches) that I had collected from participant observation. I also wrote a research diary or summary about the fieldwork (See an example in appendix 5). I transcribed data collected and recorded in interview immediately after each interview. This allowed me not only to note down what participants had said, but other elements that I perceived in the process. However, transcribing is a time-consuming activity. If I was not able to transcribe the whole thing, I would just transcribe the key phrases and re-listen to the recording the next day. After finishing transcribing, I would often write thank you emails to interviewees. It was very useful to write these emails after transcribing because it offered the chance to ask the person to clarify any confusions and remind them of any resources they had promised to provide.

Building an individual folder for each piece of fieldwork was very useful because it enabled me to pull relevant fieldwork together under the same theme/site very quickly in the analysis stage (see section 3.4). Each folder might contain data such as, written materials (sometimes I scanned the notes), photos, recordings, and interview transcripts. They would also contain my own reflections and analysis, such as my research diary, initial analysis notes, and my reflexive diary. In terms of documents, and artefacts that I collected from the field, I archived and stored them in different folders in locked cabinets. At the end, I organised my data chronologically in digital and physical spaces. Apart from pulling everything together and writing reflections, I also formed the habit of logging key fieldwork information in an excel sheet. This sheet contained categories of series numbers, time, negotiated access, recording, material objects, interviews, initial analysis, and so forth. This index system provided me with an overview of my fieldwork and made the later data retrieval easier.

3.4 Data analysis

Data analysis is not the last phase of ethnographic research. Ethnographers do not gather data blindly in the field, then bring it all back to home to see what they find out from it. Instead, they conduct many levels of analysis in the research process. As you can see from the descriptions above, the way the ethnographic data is constructed is never raw because it has been partly analysed in the research design and data collection process. For example, in the 'general gathering stage', I analysed and compared data that I had gathered in different sites. This gave me ideas about how to select participant observation sites. When taking the observation notes, I also noted down any analysis ideas. After observation, I would write down initial analysis in my research diary. In preparing for interviews, I often jotted down ideas in my interview checklist about why I wanted to interview a particular person and what I wanted to ask them. The questions I wanted to ask were also informed by my analysis. During the interviews, I would also note down any initial analysis ideas. So, the analysis is an ongoing process which is tangled up at every stage of research including the research design, data collection, data handling (e.g. coding, indexing, sorting, retrieving), theorising, and writing (Coffey and Atkinson, 1996). As Ezzy (2002) argues, data collection, analysis and writing up are inextricably linked in ethnographic research. O'Reilly (2005) calls this interrelated process an *iterative-inductive* approach where researchers swing back and forth between research design, data collection, and analysis. They continually do analysis and write up during the research process, and this can lead them to more data collection and writing up. So, it is difficult to say that there is a data analysis stage in ethnographic research. However, below I would still like to provide you with a sense of the data analysis through introducing key data analysis activities, including sorting, coding, re-coding, and writing. Before going in details about data analysis, it is necessary to address the relationship between data analysis and theorising. It might be not a convention to see theoretical discussion in a methodology chapter, but it is relevant to this research because theorising is integral to analysis and not a separate stage.

3.4.1 Theorising and data analysis

In terms of the relationship between theory and ethnographic research, many ethnographers are more in favour of the inductive approach than the deductive approach. They hold the attitude that researchers begin with an open mind and as few preconceptions as possible. However, it is widely accepted that it is impossible to start out on ethnographic research without preconceptions (Berg, 2001; O'Reilly, 2005). As Ezzy (2002: 10) further points out, "*all data are theory driven. The point is not to pretend that they are not, or force the data into theory*". O'Reilly (2005) provides a solution to this dilemma. She suggests we use the *iterative-inductive* lens to look at the relationship between theory and ethnographic research. The *iterative-inductive* perspective regards ethnographic research as an ongoing simultaneous process of inductions. This attitude helped me think about the choice of theory for this research. On the one hand, this approach accepts the fact that ethnographic research is more or less directed by theories. On the other hand, it encourages researchers to embrace the beauty of annoying moments in research, such as unexpected data, the initial framework proving to be wrong, and things that the initial theoretical framework cannot explain. The advantage of this approach is that it provides fluidity and flexible space for ethnographic research. It allows the researcher to go back and forth many times to find a suitable theoretical framework to interpret the data.

In order to find an appropriate framework to interpret the data, I went through an *iterative-inductive* process. I formed the habit of keeping theory notebooks where I constantly logged my thoughts about possible conceptual tools; recorded whatever I read about those concepts; and applied them to analyse the data. Finding a suitable theoretical framework and conceptual tools for this research was not straightforward because when I immersed myself in the field to study something fluid and continue evolving, it was difficult to immediately see the bigger picture. So, I went through an *iterative-inductive* process of theory building, testing, and rebuilding, to find a suitable framework. Below, I briefly address the *iterative-inductive* process of selecting the theoretical framework.

(1) The initial theoretical framework

Based on empirical data that I gathered between March 2015 and September 2015, I tried to form the theoretical framework. Taking the key elements that I identified from the empirical data into account, such as heterogeneous actors, alignments, expectation, and an attempt to diffuse. I pulled together conceptual tools from four sources to build an initial theoretical framework. The first source was Actor-Network Theory (ANT). ANT could have been suitable because the empirical data showed that the innovation process of OPHC involved many human and non-human elements, such as humans, sensors, the dome, money, text, and many others. ANT is relevant here because it provides a series of useful conceptual tools (e.g. *heterogeneous engineering*, *engineer-sociologist*, *translation*) to analyse how heterogeneous things align to generate effects. In other words, how do various elements work together to reach the goal of OPHC? The second intellectual resource comes from Andrew Barry's work. Especially his work on the *technological zone* and *citizens in technological society*. The *technological zone* suggests the conduct of government operates not only in territorial boundaries but also in relation to the *technological zone* formed through the circulation of technical devices and practices (Barry, 2001: 3). The element of *intellectual property rights* and *standardisation* are considered important to unify and harmonise the *technological zone*. While, the concept of *citizens in technological society* sheds light on the relationship between citizens and technologies. He argues that interactive technology is often regarded as a way to engage citizens in what he calls the technological society. The interactivity implies a less rigid articulation of bodies and objects, because through interactivity, subjects are not disciplined, instead they are allowed (Barry, 2001: 148). Barry's work was considered relevant to this research in two ways. First, because OPHC has the ambition to diffuse to another cultural context before it fully materialises in Harbour City. One good example is its ongoing communication with Delta City. The conceptual tool, *technological zone*, seemed useful to interpret what was happening in the Harbour City to Delta City communication site. Second, the discourse of OPHC highlights the citizen engagement elements. For example, the goal to build a Data Dome for citizens to view and interact with urban data. The element of citizens and interactive technologies links to Andrew Barry's observation on citizens in a technological society.

The third and fourth sources are from the Sociology of Expectation (SOE) and the Sociology of the Future (SOF). These contribute to understanding the role of vision in an innovation process. In the empirical data, I found the element of vision to be pervasive in the innovation process of OPHC. However, the element of vision is insufficiently addressed in ANT. To fill this gap, I first turned to the Sociology of Expectation (SOE). SOE provides fruitful insights about the role of vision in an innovation process, such as the *performative role of vision* (see more in Chapter 4). However, I also noticed that SOE faces the criticism from SOF that it does not pay attention to the immaterial aspect of expectation and does not explain how the layerdness of expectations work together. Although SOF also does not provide answer to these shortcomings, it suggests direction to expand the way we think about vision. So, I decided it was necessary to take SOF's insights into account as part of my initial framework as well. In order to show how the four intellectual sources could be pulled together as a coherent framework, I first illustrated them in a diagram in my theory notebook (**Figure 6**) and then designed a tidy version (**Figure 7**).

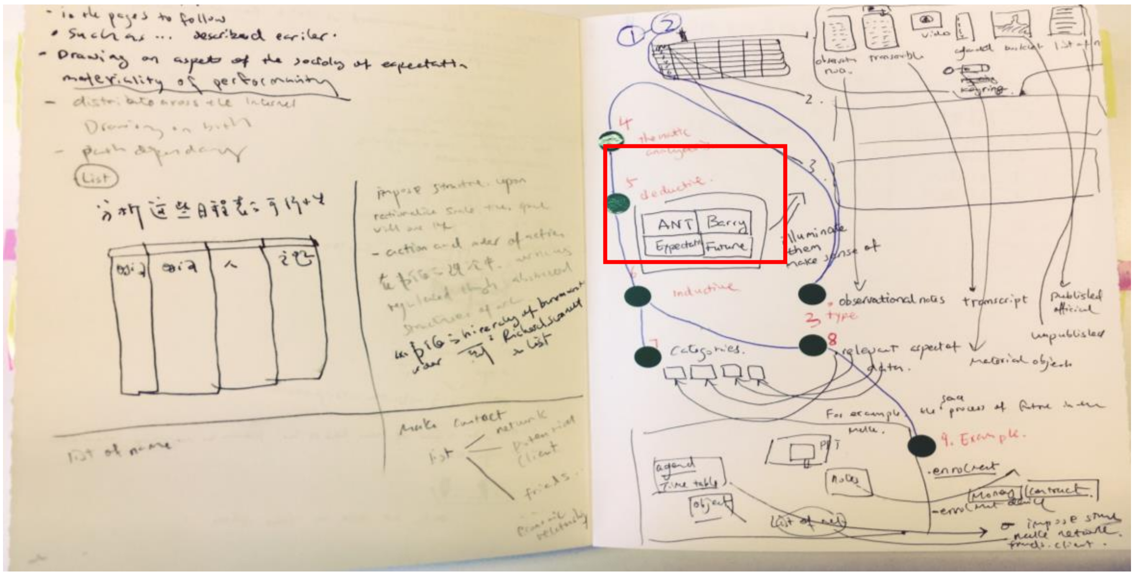


Figure 6. *The first attempt to assemble the initial theoretical framework in a notebook*

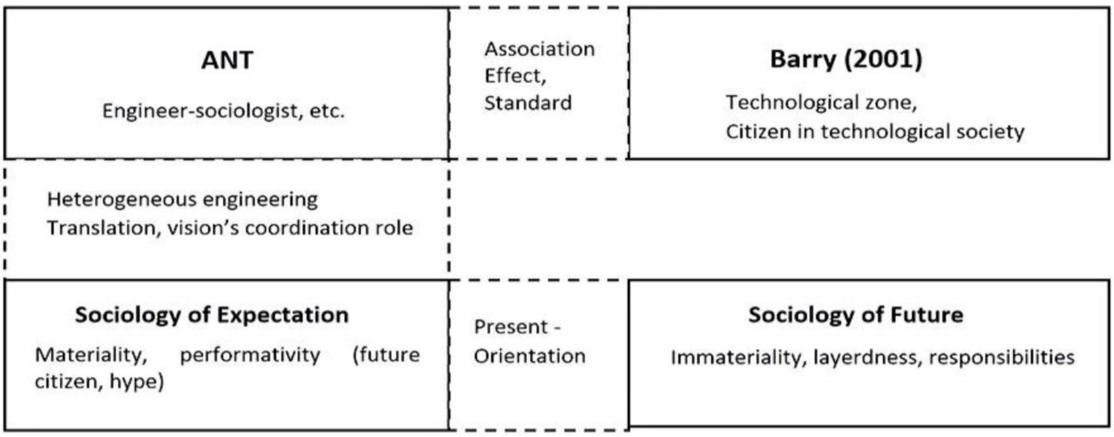


Figure 7. *The initial theoretical framework*

(2) Rethinking the theoretical framework

As the research progressed, new data emerged which made me rethink my initial theoretical framework. It is acceptable for ethnographers to modify theoretical framework in the process of research. As Clifford Geertz (1973) argued, theoretical ideas are not created wholly anew in each study and they are adopted from each other. Ethnographers test theories in the process of using them. If the theories are useful, they are further elaborated and go on be used (Geertz, 1973; Hammersley, 1992).

There were two major periods in the research when I needed to rethink the initial theoretical framework. The first time happened between February 2016 and April 2016. I had collected a lot of data from the Data Dome site and the Harbour City to Delta City smart city communication site. The initial idea to use the conceptual tools *technological zone* and *citizens in technological society* to interpret both sites was challenged. I had followed the project for nearly nine months at the Data Dome site. The Data Dome project was still at the exploration stage. No real-time interactive application had been produced at this site and citizens did not interact with data in the dome. So, the empirical data produced at this site did not really relate to the conceptual tool *citizens in technological society*. What could be observed at this site were the difficulties of building applications and the processes of aligning developers. So, I needed to find other conceptual tools to understand what was actually happening. Second, I finished data collection at the Harbour City to Delta City smart city communication site. I initially wanted to apply the *technological zone* to understand the diffusion of OPHC. So, I paid attention to the data that was associated with *standardisation* and *intellectual property rights* at this site, because both are key elements to form a *technological zone*. However, from what I observed at this site, the issue of *standardisation* and *intellectual property rights* were not salient in the diffusion process. This does not mean Barry's (2001) work is wrong, the diffusion of each smart city project has its unique characteristics. For example, smart city innovation is a system innovation which consists of a wide range of technologies and most of them are novel. It is really hard to form a unified standard and get IP protection in the early stages. Second, the OPHC did not diffuse a technological product, instead it diffused a vision. So, I needed to find conceptual tools that could interpret those characteristics.

The second period happened in May (2016). I realised ANT was not sufficient to interpret the innovation process of OPHC. This mainly arose from three aspects. First, through studying the history of OPHC, I found that OPHC emerged as an accident rather than from a strategic plan. From ANT point of view, alignment always starts with *problematisation* (Callon, 1986). This was clearly not the case with OPHC, as you can read about in the Chapter 5. Second, the emergence of OPHC was a result of interactions between local actor networks and actors at the national level (See more in Chapter 5). The flat ontology of ANT does not emphasise a structured difference between the micro level and the meso/macro level. So, ANT cannot explain the long-time negotiation process between local actors and the constraints from the meso level (e.g. national government, law, telecom companies). Third, the innovation process at the Data Dome site, the Harbour City to Delta City smart city communication site, and the Citizen Sensing site also required appropriate conceptual tools to make sense of them. Although ANT efficiently shed light on what was aligned and what did not align, there was more to the innovation process. For example, in the case of the Data Dome, ANT might explain the alignment of human and technology actors, but it neglects the large amount of time that actors spent trying to figure out what to do next; conducting experiments; reflecting on their actions; and exploring new pathways, etc. So, persisting with ANT, felt like forcing the data to fit the theory. This would not only go against the validity of the research, but also show no respect for the people involved in the story of OPHC.

(3) Re-configuring the theoretical framework for this research

In order to find suitable conceptual tools for the empirical data, I turned to the socio-technical perspective of Transition Studies. The socio-technical perspective of Transition Studies is very similar to ANT. It treats socio-technological change as a result of the overall *configuration* of technology, policy, market, cultural meaning, and so forth. The analytic tools in the socio-technical perspective of Transition Studies, in particular, Multi-level perspective (MLP) and Strategic Niche Management (SNM) are useful for interpreting what happened in the case OPHC which I will explain later. I choose the socio-technical perspective of Transition Studies as a theoretical framework for this research for four reasons. First, the smart city project, OPHC, has a transition ambition. This is reflected in two aspects. One aspect is the design of the project. OPHC seeks to create a programmable infrastructure as a platform that will enable a wide variety of actors using digital technologies to deal with urban problems. It is envisioned as a system innovation and design for a different practice from how cities are operating now. Another aspect is the SDN technology that OPHC adopted. This technology claims to bring transition possibilities to the existing network industry. Second, this approach sheds light on the structure that OPHC is embedded in. The core of the socio-technical perspective of Transition Studies is the Multi-level perspective (MLP). It regards transition as coming through interaction between three analytic levels: *niches, regimes*, and *landscape* (see details in Chapter 4). The emergence of OPHC is not just alignment at a local level. Instead, it is a result of interaction between the local level and the meso level (*regime*). The use of MLP can clearly acknowledges the structure restrictions of OPHC. Third, the management approach of the socio-technical perspective of Transition Studies, called Strategic Niche Management (SNM), provides a series of conceptual tools (e.g. niche internal process) to understand innovation activities in many sites that ANT does not pay attention to. Fourth, it distinguishes between *local niches* and *global niches*, and the spatial dimension of SNM can help shed light on the diffusion of OPHC. I discuss all of these in Chapter 4.

In terms of exploring the role of vision in the innovation process, SNM emphasises the role of vision in helping form a *niche*. However, there are still some aspects of vision that are not addressed in SNM. In this sense, the conceptual tools from the Sociology of Expectation are still useful to this research and compliment SNM. Both Transition Studies and the Sociology of Expectation (SOE) are compatible with each other because they share some similar scholars and thinking traditions (see more in Chapter 4). In terms of the Sociology of the Future, although it points out the shortcomings of SOE, it does not provide sufficient conceptual tools to interpret the empirical data of this research. So, I decided to drop Sociology of the Future to make the overall theoretical framework coherent.

In the end, the theoretical framework for this research consists of two main intellectual resources: the socio-technical perspective of Transition Studies and the Sociology of Expectation. I have indicated these here to help explain the analysis process and I will provide a detailed review of this framework in Chapter 4.

3.4.2 The process of data analysis

(1) Sorting and coding data

The first step of data analysis is to organise a large amount of empirical data through the process of sorting and coding. Sorting data is a process of putting data into different boxes or categories. In total, I sorted the data into six categories: (a) *Data Dome,* (b) *Harbour City-to Delta City smart city communication,* (c) *Citizen Sensing,* (d) *the OPHC infrastructure,* (e) *the performative role of vision,* and (f) *the history of OPHC*. The categories were informed by the data collection and management process. One way of sorting data is to put events that relate to one site together. This would include *Data Dome, Harbour City-to Delta City smart city communication,* and *Citizen Sensing.* Another way of sorting is to put different events that are associated with one topic together. The categories that gradually emerged in the research process included the *OPHC infrastructure*, the *performative role of vision*, and the *history of OPHC*.

After sorting the data into categories, I started to code it. The coding process is not straight forward. There is a need to constantly re-code and re-order data. I chose to use the computer software, NVivo, to conduct initial coding because the software made it easy to make connections between different themes, make changes, and manage a large amount of data. I built six folders in NVivo and imported the six categories of data. Then, I started the coding process. It is worth noting that I always conducted coding activities during the data collection process. For example, I identified evolving themes, tested them with my participants, and tried to find a theoretical framework to interpret the data. So, when I came to the coding stage, I already had some idea about coding. I use the thematic analysis method to code the data. There are two types of thematic analysis: 'inductive thematic analysis' and 'theoretical thematic analysis' (Braun and Clarke, 2006). The former suggests researchers read the data many times and see what emerges from it, while the latter requires researchers to apply theoretical frameworks to search for corresponding elements within data. I applied both inductive and theoretical thematic analysis to code the data. For example, when I analysed data from the category *performative role of vision*, I read through all the data about how innovators communicate the vision of OPHC. I found that the rhetoric of *"first"* can be identified in almost all discourses. So, I labelled the relevant data under the code *"first"*. This is an example of how I used the 'inductive thematic method' to analyse the data. I also used the 'theoretical thematic analysis' to shed light on the innovation process. For example, according to the Strategic Niche Management, there are three niche internal processes (*articulating expectation*, *building social network*, and *learning)* that contribute to developing a *niche* for novelty. So, I looked for relevant data in the three innovation sites (*OPHC infrastructure*, *Data Dome*, and *Citizen Sensing*) that related to the three niche internal processes.

(2) Using drawing and objects to assist analysis

Sorting and coding data through software helped me to reduce a large volume of data to manageable themes. However, analysis is a result of repeating interactions between conceptual tools and data (Coffey and Atkinson, 1996). The analysis can happen in any space, it is not necessary to restrict it to software. I found drawing on a piece of A3 paper is a convenient way to conduct data analysis. I would draw diagrams and symbols; write notes; and apply arrows to make linkages between codes, themes and conceptual tools. Fetterman (1998) argues that visual representation is a useful analysis tool for ethnographic research because it helps to crystalise networks, understanding, and pave new paths to explore. Latour (1986: 22) has a detailed study about the function of inscription in knowledge production. He summarises several advantages of working on two-dimensional paper. For example, paper is easy to move around and contents on a paper are immutable in the moving process. Paper is flat and the scale present on paper can be modified at will. And it is possible to superimpose several images on a single piece.

Visual analysis on A3 paper contributed to this research in several ways. First, it was an extremely useful way for me to map the innovation process in each site and synthesise empirical and conceptual themes into stories. For example, in order to have a clear understanding of the innovation process at the Data Dome, I listed all themes (empirical and conceptual) that I had identified from the coding stages on a piece of paper. Among those themes, I identified three key episodes at the Data Dome site. Then, I drew a series of three rectangular boxes on a piece of paper to represent a sequence of three key episodes in the innovation process of the Data Dome (**Figure 8**). Within each box, I wrote down the key actors and technologies. Around the boxes, I noted down key inductive themes and theoretical themes (see more examples in appendix 6). Drawing empirical and theoretical themes on a piece of paper allowed me to have an overview of the innovation process at a particular site.

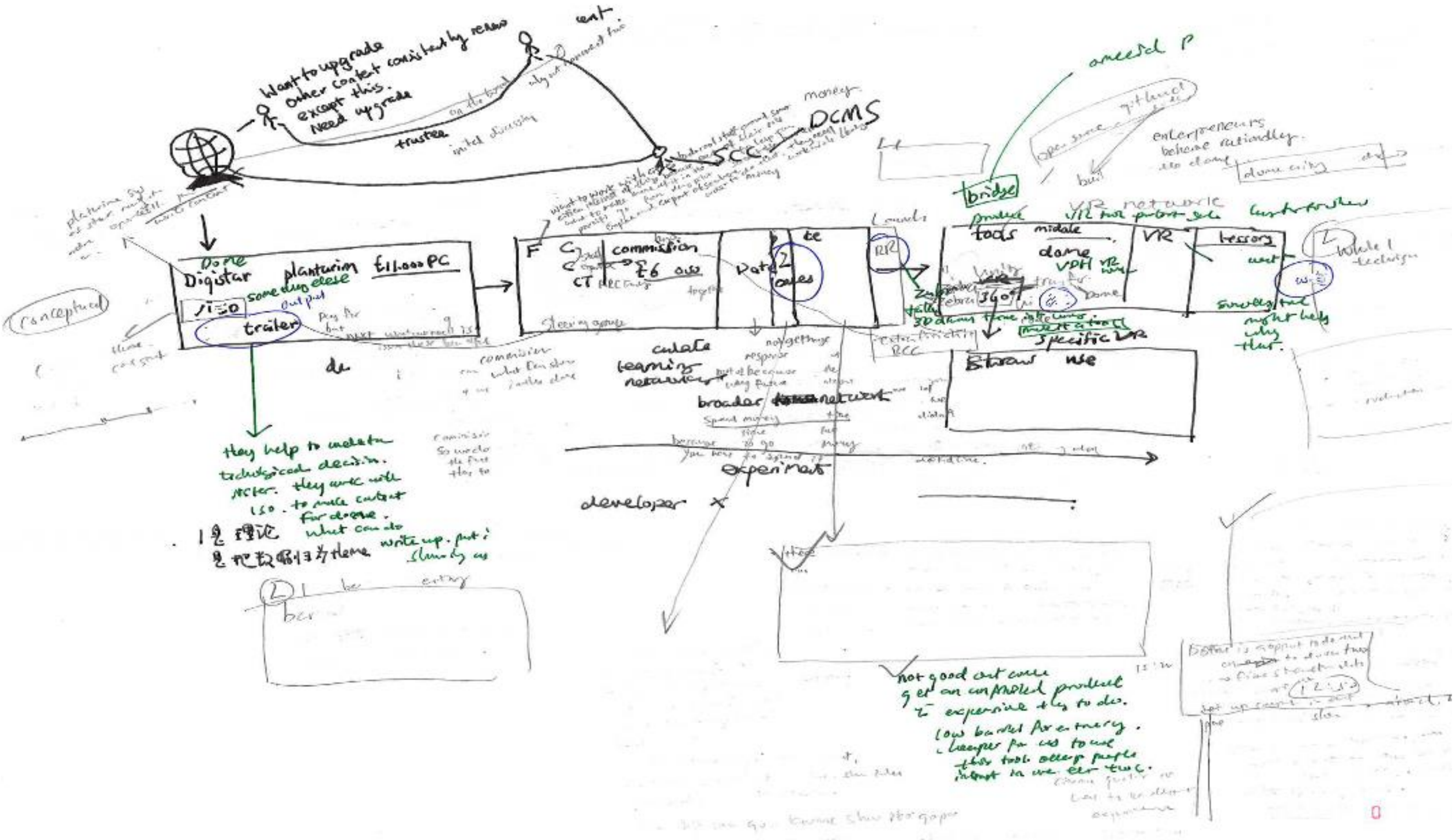


Figure 8. *Using drawing to figure out the innovation processes of the Data Dome*

Second, drawing allowed me to simplify inscriptions; pull together a large number of events in one space; and apply conceptual tools to relevant data. This function is similar to La Perouse who travelled the Pacific with the mission to create a better map of Sakhalin. He drew maps of the places he went to and together they formed a picture that could be used to understand whether Sakhalin was an island or not (Latour, 1986). In the case of OPHC, the innovation process of OPHC happened in multiple sites. I collected data from different sites and came back with key insights from each one. Then, I pulled them together to understand the innovation process of OPHC. For example, **Figure 9** is one of my analysis notes. In this note, I gathered themes from several key sites, such as the *Data Dome*, *Citizen Sensing*, and *Harbour City to Delta city communication*. Together they show the innovation process of OPHC within and beyond Harbour City. The bubbles on the upper-left corner of the paper shows the key sites involved in the innovation process. On the same page, I also note down conceptual tools that are useful to interpret innovation processes, including *niche experiment*, *local niche*, *MLP*, and *spatial dimensions of niche development*. The paper provided me with a space to weaves multiple stories in a single space.

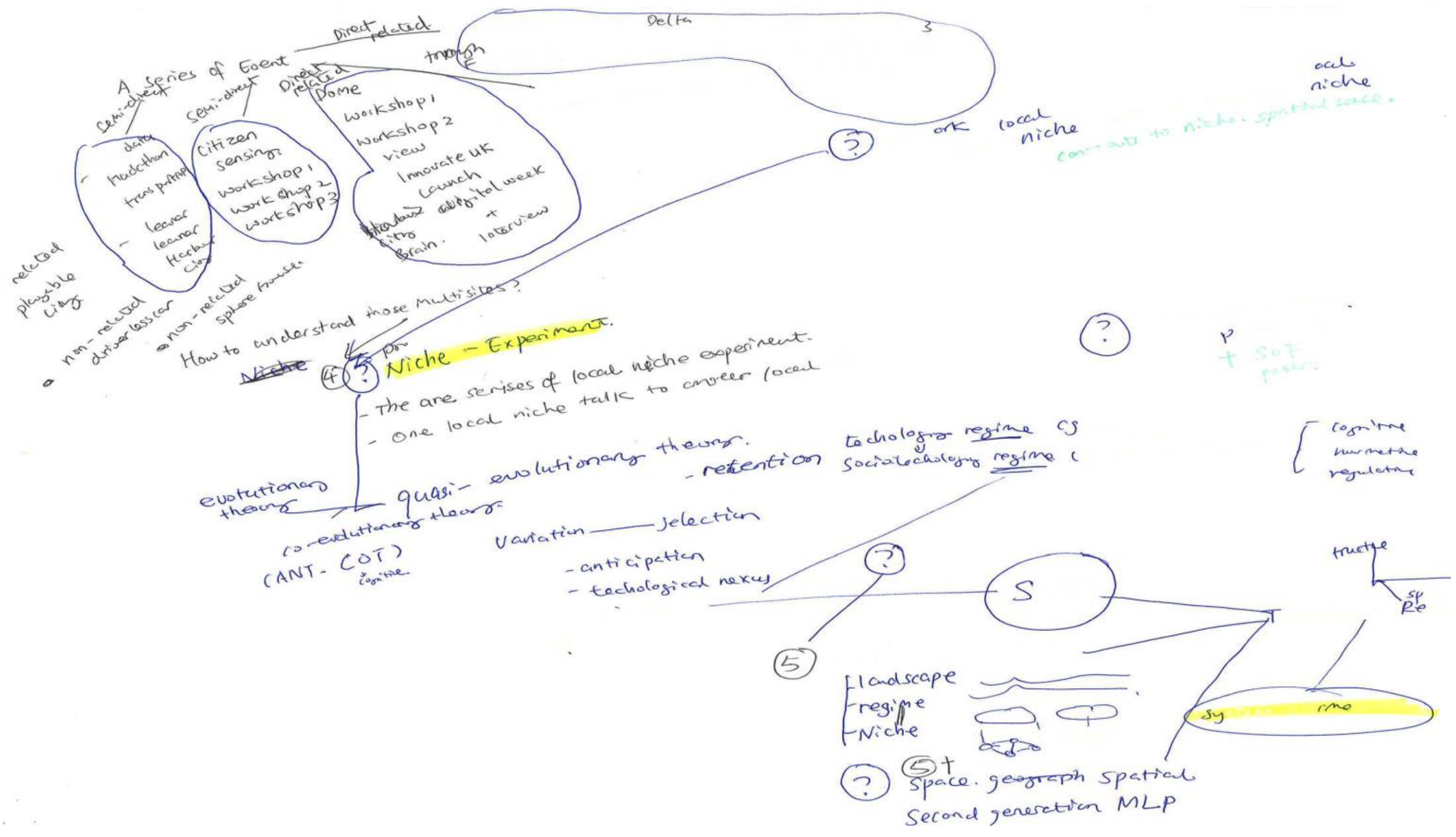


Figure 9. *Pulling data from multiple sites and applying conceptual tools onto a piece of A3 paper*

However, when I worked with large amounts of data/themes from different sites in response to specific issues, the analysis on two-dimensional paper showed its limitations. No matter how big the piece of paper, the relationship between themes are hard to visualise by drawing alone. I often ended up with messy arrows, notes, and lines which confused more than clarified. This is because what is written is fixed, drawings do not provide the ‘affordance’ (Gibson, 1979) to move conceptual tools, signs, and figures around quickly while conducting analysis. In order to more easily reshuffle, recombine, and make a series of different cuts of data, I needed a tool with different properties; it had to be moveable, immutable, presentable, and be able to combine codes/themes. Mind map software was an option, but I ended up inventing a 3D embodied tool which has similar function to the mind map. I bought a box of Jenga. On each piece of wood, I attached a white sticker which enabled me to write words on it. Those words were the main components that I had found in the innovation process of OPHC, including the names of key actors, organisations, projects, technologies, and expectations. In order to easily identify actors from different sites, I added coloured stickers to distinguish them. For example, blue stickers represented actors at the Data Dome site. **Figure 10** is an example of my reconfigured Jenga.

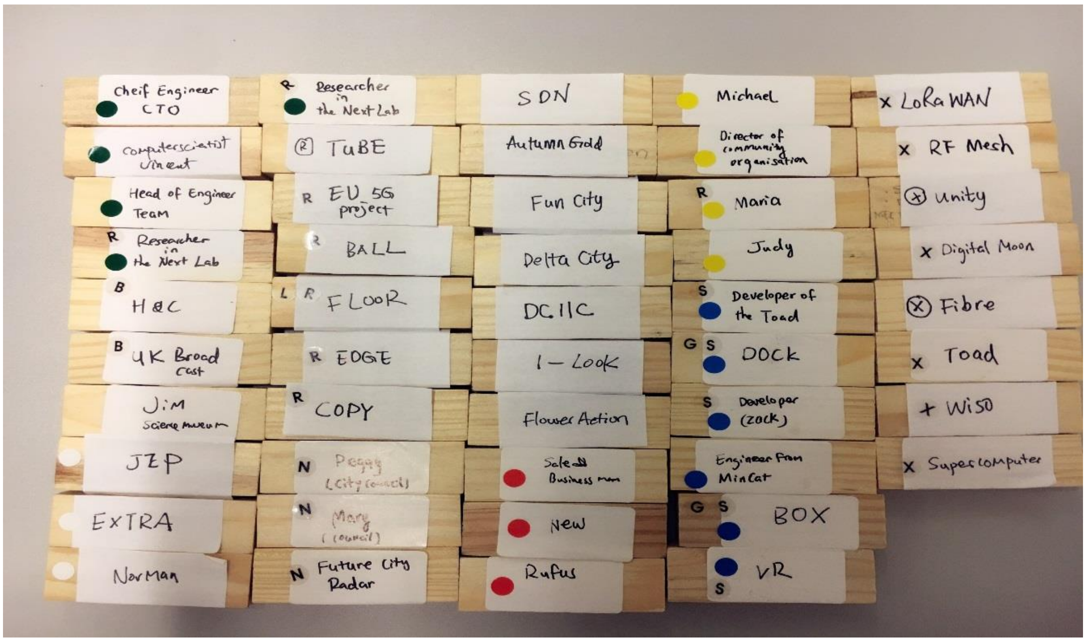


Figure 10. *Reconfigured Jenga as a data analysis tool*

When I dealt with complex data sets across sites, I would often move my reconfigured Jenga around a large piece of paper. The paper allowed me to write notes and conceptual tools beside the Jenga. It not only helped me to crystalise my thinking and analysis, but also enabled me to record the placement of Jenga at the end of the day. This provided what Latour (1986) called optical consistency. It enabled me to recall unfinished analysis and continue the analysis in the future. **Figure 11** is an example of how I used Jenga, paper and written notes to conduct analysis. It records the moment that I was trying to figure out the question "*to what extent does the innovation of OPHC in multiple sites fulfil the prospective structure of OPHC (the vision of OPHC)?*" In order to answer this question, I needed to look across data and themes from four categories (*Data Dome*, *Harbour City to Delta City communication*, *OPHC infrastructure*, and *Citizen Sensing*). I decided to use Jenga to assist in the analysis. As we can see in **Figure 11**, the whole analysis occupied six A3 pages. I drew the *prospective structure* of OPHC on the paper, then arranged actual actors and artefacts from four categories around the *prospective structure.* Around each cluster of Jenga, I also noted down the conceptual tools. For example, I drew the conceptual tool *promise and requirement cycle* at the lower left part of the figure around the Citizen Sensing site (see the full explanation of this conceptual tool in Chapter 4 and see the actual analysis of this theme in Chapter 6). In this specific case, without the help of Jenga, it would have been much more difficult for me to visualise and make sense of the large number of themes in answer to a specific question.

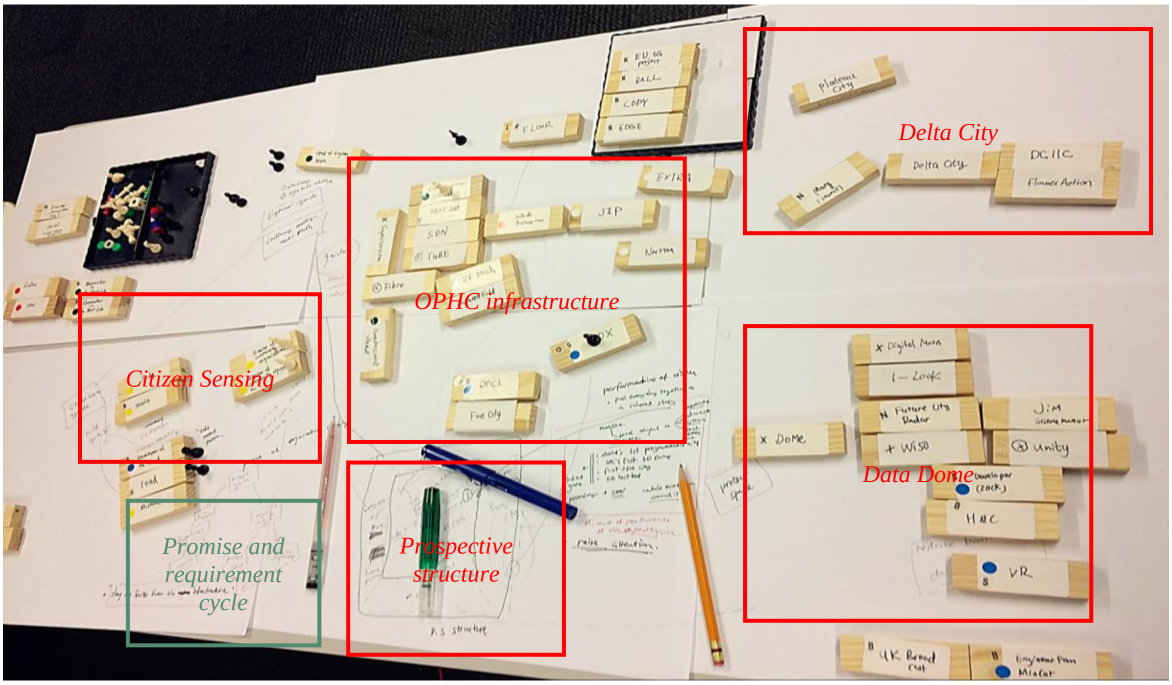


Figure 11. *A photo recording of the use of Jenga to analysis data*

(3) Writing as a form of analysis

Apart from sorting, coding, and figuring out story lines, matching themes with conceptual tools, and arranging themes in answering questions, writing is also a process of data analysis. Coffey and Atkinson (1996) argue that writing helps to deepen the level of analysis. They say that, "*analytic ideas are developed and tried out in the process of writing and representing*" (Ibid: 109). This is especially true for this research because a lot of codes, themes, and conceptual tools were generated in the analysis process. Sometimes, merely drawing connections on papers did not allow me to see the contradictions or logic inconsistencies in detail. So, I needed to weave codes, themes, and conceptual tools into text to see whether the use of the concept was precise. To what extent did I capture the story of OPHC? How did they work together to answer the research questions? What themes were not relevant for this research but could be explored in future research? Writing was a way to help me reach these goals.

Writing as an analysis process for this research was an ongoing process and it can be divided into three stages. The first stage was writing alongside the data collection process. I sent my supervisors monthly reports. Those reports often contained analysis of the data that I had collected in a specific period of time. For example, in the April 2016 report, I reported my observations in the Harbour City to Delta City smart city communication site. In the report, I explained why I needed to modify the initial framework. I also presented several themes about the difficulties of diffusing the vision of OPHC to Delta City. The writing at this stage was useful as a way to work with the data in a very detailed way, test the initial conceptual tool, and conduct some initial coding.

The second stage of writing happened between July and November 2016. I wrote six essays on six categories: *the history of OPHC*, *the programmable infrastructure of OPHC*, *the Data Dome*, *the Citizen Sensing, the case of Delta City, the performative roles of the vision*. Within each essay, I wove the themes and conceptual tools together. I printed these essays out, cut them section by section, and pasted the sections on an eight-meter-long background. Between each section, I left some empty space to write notes. I also wrote key arguments and conceptual tools on different coloured stickers which were easy to move around (**Figure 12**). This was very useful. On one hand, it provided me an overview of the empirical data and conceptual tools for this research. On another hand, it allowed me to make linkages between analysis units and establish an ordered relationship between them, and examine the use of the conceptual tools in detail.

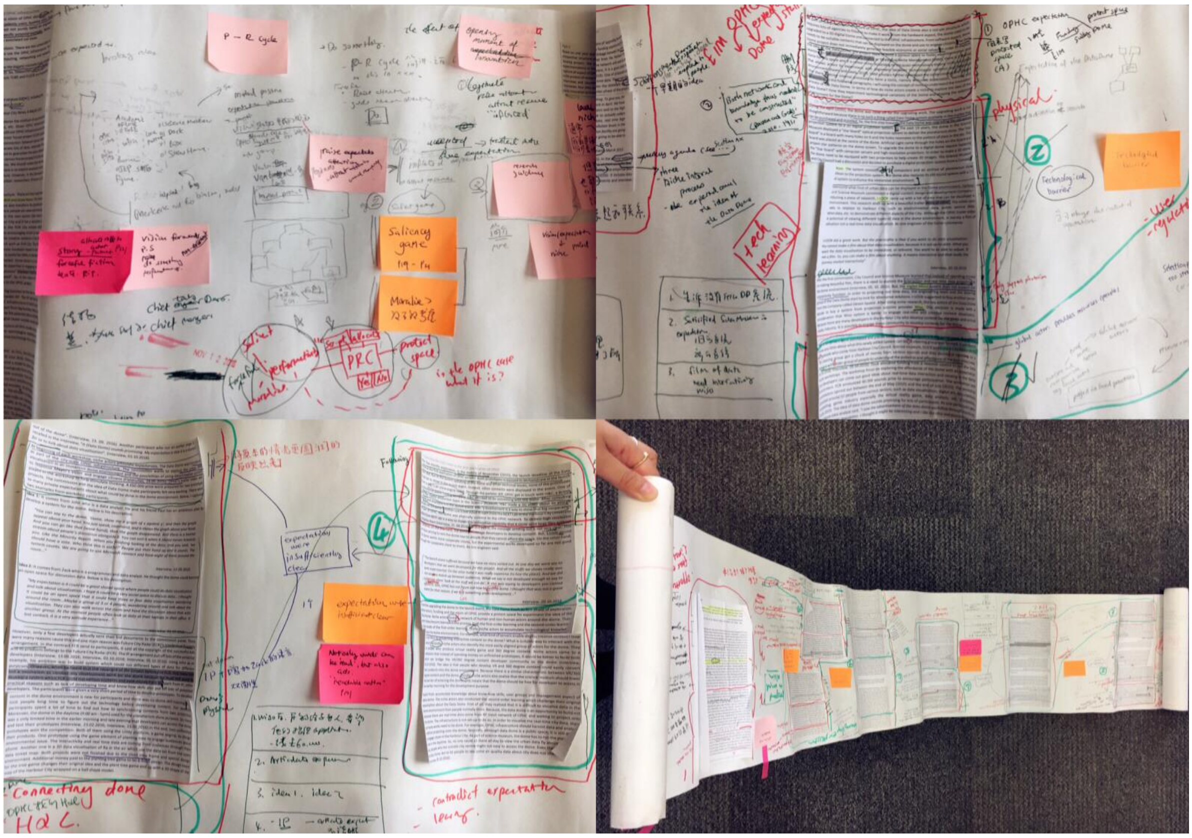


Figure 12. *The examination of data and conceptual tools in detail*

Although the examination of themes and the use of conceptual tools according to different categories provided me with some confidence about the appropriate use of conceptual tools to interpret the data, I also needed to think about how to synthesise different analysis to answer the research questions and figure out how to present such a messy innovation process to people who are not familiar with OPHC and who are not technology experts. It required me to think of a forest rather than a wood. So, in the third writing stage, I arranged the six analysis categories into three chapters. The first chapter drew on the analysis of the *history of OPHC* and some data from the *performative role of the vision.* Together they helped to answer the question *how did OPHC emerge in Harbour City*? I put the category *OPHC infrastructure, the Data Dome* and *the Citizen Sensing* into one chapter. They show different aspects of how OPHC was rolled out in reality. In the last Chapter, I drew on analysis in *the Harbour City to Delta City communication* and the *performative role of vision* to discuss a phenomenon in the innovation process; diffusion. These three chapters together answered research question 1: *what is the innovation process of a local smart city project?* Within the three chapters, I also stressed the roles of vision and citizens in the innovation process to answer the second and third research question which focus on exploring the roles of vision and citizens in the innovation processes. This stage of writing aimed to make sure that the codes, themes, and conceptual tools were linked with each other to reveal the innovation process of OPHC. It was also a process of crafting and getting rid of unnecessary narratives and analysis. For example, I found the theme of *intermediary actors* in the diffusion of OPHC. I did some analysis around it in the original writing, but during the third writing process, I realised that I did not have enough data to trace *intermediary actors*' effect in the OPHC innovation process. So, I decided to delete the analysis, put any relevant data in the appendix, and set aside this theme for future research. However, on reflection, one drawback of writing throughout the data collection and analysis process was that it did not always allow me to keep proper distance from the data. I noticed this in the late stage of writing where I had more distance with the field. I started to realise I was sometimes too focused on exploring details and this blinded me to the bigger picture or larger patterns.

3.5 Ethical considerations

The value of ethnographic research lies in producing knowledge, but this does not mean that other values should be ignored during research (Hammersley and Atkinson, 2007). It is a dilemma that on the one hand, ethnographers need to take responsibility for their professions.

On the other hand, they should also consider the people whom they study. Ethnographers often find themselves standing at a crossroads trying to make decisions which satisfy both the demands of the research and morality (Fetterman, 1998). Ethics considerations pervade every stage of ethnographic research, ranging from negotiating access to the write-up phase. I was aware of ethical issues all the way through the research. Below, I address several key ethical considerations and decisions of this research.

3.5.1 Informed consent

Researchers should gain meaningful consents from participants. The informed consent in this research mainly involved consent for conducting participant observation and interviews. Since the fieldwork consisted of participant observation in a series of public and private events and formal and informal interviews, I used both of formal and informal consent for this research.

Before beginning fieldwork, following the BERA ethical guidelines, I thought through the ethical issues that might arise during this research and designed two documents. One document was an information sheet to tell participants enough information about the research and what it would mean for them to agree to participate to this research. The other document was a consent form. This document further ensured that participants understood their rights and how their data would be used in the research. Both documents received approval from the ethical committee of my department (see both documents in appendix 7). I used both documents to gain formal consent during participant observations and formal interviews.

For participant observation, there were four main key sites. In general, there were two types of events: private events (accessible only to a small group of people) and public events (accessible to anyone). Private events are limited to small numbers of people so in these cases I gained not only the gate keepers' consent, but also the written consent of the other participants. It is much more difficult to gain full consent for public events as it is impossible to control people who come into the field, but I still tried my best to gain as many people's consent as possible. There are several ways that I use to gain consent at public events. For registered events, I informed event organisers of my research purpose by filling online registration forms. Organisers often checked who was going to come beforehand and knew that I planned to conduct observation at the site for the purpose of studying OPHC. Some events require people to introduce themselves at the beginning of the event, and I normally took the chance to ask for consent. Sometimes, I would introduce myself and my research to people that I met in the field. As for incidental data arising from fieldwork, I would immediately gain people's oral consent. In some cases, they even signed the consent form afterwards and send it back to me by email.

In formal interviews, I would start by introducing the purpose of research. Following this I would provide time for interviewees to read the information sheet, ask questions, and sign the consent form. I would also ask their permission to record interview. It is worth noting that, consent for a long-term research can be difficult because people might forget you are researching them (O'Reilly, 2005). The best I could do was to reconfirm consent with participants. For both formal interviews and observations at private events, participants were required to sign the consent forms as a sign that they understand the information provided and were willing to participate in the research. I kept a good record of ethical negotiations. Any documents with the personal details were kept separately from the data in a locked cabinet.

3.5.2 The issues of exploitation, over-rapport, and withdrawal

During the ethnographic research process, there were many ethical issues and below I address three main issues. The first is the concern of exploitation. Ethnographers are often challenged on this because people supply information to researchers, but researchers give little in return (Hammersley and Atkinson, 2007). Therefore, researchers are recommended to give something back as a demonstration that the ethnographer is not an exploitative interloper, but has something to offer (Lassiter, 2005). Researchers can balance this through asking themselves what participants can benefit from the research and how their needs can be served. For this research, I can give back in two ways. First, the outcome of this research will make practical intellectual contributions to local smart city innovation. It can provide local innovators with a holistic view of the innovation process and inform them about what can be improved. Second, during the data collection, I balanced the exploitation issue by providing volunteer services for participants. For example, in the entire Harbour City to Delta City programme, I provided Harbour City participants with assistance and advice, such as translation and assisting with delegation visits. While in interviews, I often provided interviewees drinks and food as a goodwill gesture to demonstrate appreciation for their time.

As the research progressed, the services I did in the field not only fulfilled the need to give something in return, but also helped me to win people's trust and built up a good reputation. Since Harbour City is not a big place and social networks in the City are interconnected, the trust established in one site sometimes spread to other sites. Gradually, I became very well accepted by local communities; being enrolled onto people's mailing list, being added as their Facebook friends, and being invited to different events as their guests. Sometimes, people even invited me for tea, suppers, and birthday parties. I decided to accept these offers, because I wanted to maintain a relationship of trust with my participants and consistency is the basis for human trust. I could not pretend to be their friend when I needed them and act as a stranger when I no longer needed them. That would hurt people' feelings. Also, to attend those private activities deepened my thinking and helped me to understand my research context and the people within it better.

However, this generated the second concern which was the danger of 'over rapport', of the researcher going completely native. As a result, researchers can lose their critical faculties and become ordinary members of field (Brewer, 2000: 60). In the whole research process, I am always trying to keep a balance between maintaining a distance with people and being truthful to people. At the beginning, I maintained a good distance with people but as project progressed, this became more and more difficult, especially, in the later stages of data collection. I realised that I started channelling in line with existing networks of friends and boundaries. The attempt to maintain distance even caused what Hammersley and Atkinson (2007) calls the 'marginal native' stress symptom, that on the one hand, ethnographer resists over identification with the native and on the other hand, the ethnographer feels bad about the divided loyalties for native. I am glad that I became friends with actors at the late-stage of this research, otherwise I might not have stepped into the dangers of over-rapport but also have experienced more 'marginal native' stress symptoms. I felt much relief after I had finished data collection.

Once good quality relationships are established in the field, it is not easy to cut them off. So, this leads to my third concern: withdrawal. Withdrawal from the field is not a straightforward matter. Gradual withdrawal is recommended by many researchers. Although I finished fieldwork, I still stayed in Harbour City for about a year to write up my thesis. This provide me with an advantage in gradually leaving the field. From early November 2016 onwards, I kept a distance from the OPHC project. But, this does not mean I broke up all the relationships that I had established with people. Most ethnographers retain friends and acquaintances from their periods of fieldwork, sometimes a long term (Hammersley and Atkinson, 2007: 91). In my writing phase, I still maintained contact with many actors who were involved in my research. I have been invited to private activities, such as going to theatre, attending a Christmas dinner, participating in a charity cooking event, and going to see exhibitions together.

3.5.3 Confidentiality and anonymity

Finally, I will discuss the confidentiality and anonymity issues of this research. O'Reilly (2005) defines confidentiality as applying to anything the researcher hears. It can only be shared between participants and researchers. Researchers should respect the privacy of those they are researching. I have taken confidentiality seriously and maintained good practice all the way through the research. This is reflected in several aspects. First, I often gained very detailed descriptions of human interactions. For a while, I thought that I was the only person to see the bigger picture. Because people from different sites rarely knew what others were doing. A good side of this is that I was able to collect rich data. The critical side is that I heard many people's "secrets" and what they plan to do in the future. Since those plans normally do not bring harm to other people, I decided that I would just quietly wait for things to happen and bring as little impact to the innovation process as possible. Second, as the research progressed, I gained acceptance into the community and this opened-up new levels of understanding of previously undisclosed symbols and knowledge. Sometimes, the information involved in how one organisation or person regarded another organisation or person. The delicate web of interrelationships in the local communities might be destroyed if I had revealed the real identity of people. So, I kept silent about those comments and allowed interviewees to switch-off the recording if they complained about someone. Third, the 'smart city' is an emerging hot research topic at the local University. During my research, many academic researchers and students in the Harbour City University emailed me and wanted to talk to me about my observations of OPHC. Although I received funding from the Harbour City University and should support research activities, in considering the privacy of my participants and the impacts my words could bring to OPHC, I decided to only communicate my observations to my participants. As for my supervisors, given they have responsibilities to guide this research, they could access my observations and I trust them to maintain the same level of ethical standards. In terms of my responsibility to my funders, I treat my return on their investment as a long-term thing, rather than short-term thing. The best way I can show my gratitude to my funder is to produce a good piece of research.

Ethnographic research rarely involves damaging consequences, but researchers should still carefully consider the likely effect on people who are involved in the research (Hammersley and Atkinson, 2007). One concern for me is the public dimension of this research, that this study is about real people and a project in a real city. The publicity of the research might potentially damage the reputation of persons, institutions, or locations. It might also hurt the feelings of people who involved. Nespor (2013) faces a similar problem. He acknowledges the difficulties of providing full anonymity in community research because it is easy for people to figure out where the place is. His strategy was to reveal the real name of city or place and anonymise the names of the streets, parents, teachers, and principals. He also altered information that might have identified them. He further points out that the research only focuses on a certain period of time. People and situations in his research had changed since he finished his study. But, stories are still valuable in the research because they allow readers to generate questions about their own experiences (Ibid: xix-xx).

I am using Nespor's (2013) strategy to deal with anonymity. I reveal the real name of the city and anonymise all the institutions and people. I have applied some techniques to disguise the identity of people and institutions. For example, I use pseudonyms to anonymise real names of participants and institutions. Sometimes, I have mixed the use of the title of the person and pseudonyms of the same person in the writing. For example, I use *a member of the Data Dome team* rather than refer to the pseudonym of the person. This provides readers with enough information about the sources as well as protecting the real identity of the person. I also evaluate levels of risk to reputation. I noticed only a few participants that could be easily identified even if I concealed their real name. So, during writing, I was mindful about every instance when I referenced these individuals. I had to justify whether the information was sufficiently important to justify revealing the identity of the individual, or attempt to find another resource for the same information. For example, in order to show readers how the spokesman of OPHC provided the rationale to the vision of OPHC, I needed some quotations from the speaker. Initially, I chose a quotation from an online video source. However, I very quickly realised that if I used the video source, I would have to cite the URL of the video. This would reveal the identity of the speaker. So, I searched for a similar quotation from the same person from other sources. In the end, I found one from my observation notes.

3.6 Reflexivity

Ethnographic research often faces the charge of what extent the outcomes of ethnographic research claim to represent an independent social reality (Hammersley, 1992). Like much qualitative research, ethnography does not match these positivist cannons (Hammersley and Atkinson, 2007). From a constructivist perspective, ethnographic data is constructed in and through the process of analysis and the writing of the ethnographer. In other words, the ethnographic work is a product of participation in the field, rather than a representation of what they describe (Clifford, 1988; Hammersley, 1992). From the 1960s onwards, two trends emerge; feminism and postmodernism attempt to address the crisis of representation. They call into question the hegemony of Western situated knowledge and the power relationship between the researcher and the researched (O'Reilly, 2005; Lassiter, 2014). For some, ethnographic research is no longer trustworthy, while others start to embrace the "reflexive turn" (O'Reilly, 2005). Reflexivity could be broadly defined as turning back to oneself. It is a process of self-reference (Davies, 2008: 4). It refers to the way in which the products of research are affected by researcher herself/himself and the process of doing research. The "reflexive turn" requires ethnographers to acknowledge that they are part of the world and think critically about how their subjectivity affects their reading, interpretation, and writing. In other word, ethnographers cannot escape the social world in order to study it and they can never truly be objective due to their personal experiences, theoretical framework, subconscious political/ideological agendas and even their sensory bias (Pink, 2009). They might influence the research at different levels, ranging from the choice of topic to the interpretation of data (O'Reilly, 2005; Lassiter, 2014). As feminist writers famously argue, "*a view from nowhere was always a view from somewhere*" (O'Reilly, 2005: 211). But this does not mean we should abandon our research or find a way to completely eliminate the effect of researchers. Rather, we should be honest and acknowledge our vulnerability (Lassiter, 2005), embracing the ethnographic experience critically and opening ourselves to try to understand how this experience works and affects our research. In line with the "reflexive turn", I kept a reflexive diary during the research process. In this journal, I constantly logged my reflections. Due to the word limit, it has been impossible to talk through them all. Below, I briefly reflect how I influenced the sampling, data collection, data analysis of this research.

Apart from my Chinese identity that I mentioned earlier, the sampling process of this research was also influenced by my personal interest in studying radical technologies. For example, I have always been fascinated by technological innovations that bring huge change to society, such as electric lighting systems, telegraphy, trains. When I read that OPHC has an ambition to revolutionise the current communications network regime through deploying a city-scale SDN solution, I was excited because it reminded me of the story of Thomas Alva Edison who sought to introduce an electrical illumination system to replace gas and oil-based lighting in 1878. My intuition told me that OPHC would be an exciting case to look at and I thought that I might stand in a historical vantage point to witness history in the making and the project's rises and falls.

I impacted the data collection process in several ways. First, my belief system influenced the way I interacted with people when collecting data. As a Zen practitioner, I tried to treat people equally despite their secular social status or class. I think this practice brings me some advantages because I am not affected by British class/status. For example, I do not have a process of evaluating people's class before approaching them for interviews. I did not realise this until I conducted an informal interview with a British participant in the field. He told me that "*you will be able to ask me for an interview because you are a middle-class professional. My neighbours (Asian working class) do not even dare to borrow a screwdriver from me*" (Research Diary, July 2016). It was a shocking moment in the fieldwork because I do not know which class I sit in and he projected a certain British class on to me. I asked him for an interview purely based on my judgement that he might provide some useful data. Second, I am an 'outsider' to Harbour City and British culture. This 'outsider' role brings me some advantages. For example, people are more open and patient in explaining things to me.

I also influenced the data analysis. First, my cultural background influenced some of my data interpretation, in the sense that I was not be able to spot certain things which I take for granted in my own cultural context. For example, I grew up in a country where infrastructures are owned and controlled by the government. So, this background made it difficult for me to understand why OPHC is only possible because the city council owns its fibre duct. That a local city council owns its fibre duct and makes it accessible to people is common sense in my mind. I did not realise how significant this was to the emergence of OPHC at the beginning. I heard people mentioning it once, twice, three times and I did not pay attention to it. Until, at a dinner table, I was sat beside a U.S scholar who emphasised the importance of the fibre duct in OPHC. At that moment, I started to realise that I needed to re-evaluate my assumption. Second, my non-native English speaking background influenced the data analysis. For example, as a non-native English speaker, when I collect data, I tend to note down people's words at face-value during fieldwork, and it takes me a while to distance what people say and conduct deeper levels of inquiries.

3.7 Conclusion

This chapter following a conventional methodological chapter sequence. It provided the rationales and a detailed account of the many important choices that I made in relation to the research design and research process. It has explained why the ethnographic approach is suitable for the purposes of this research, and why OPHC is a good smart city case to look at. It has provided a detailed picture of the boundaries of this investigation. This mainly refers to where I went, whom I talked to, and what I collected. It has also illustrated the process of data collection, management, and analysis. The descriptions were supported by the photos, drawings, maps, tools that I produced in the process (e.g. Jenga). Finally, it has reflected the concerns that arose from the ethnographic processes, including key ethical issues and has been reflexive of the researcher's own subjectivity. While talking about the data analysis, it has briefly addressed the *iterative inductive* process of selecting and configuring Transition Studies (socio-technical perspective) and the Sociology of Expectation as a theoretical framework for this research. I am going to expand on this by reviewing the key conceptual tools from both intellectual sources in detail in the next chapter.

Chapter 4

Theoretical framework

This chapter introduces the theoretical framework for this research which draws on two interrelated intellectual school of thoughts: The socio-technical perspective of Transition Studies and the Sociology of Expectation. In order to provide readers with an overview of the main conceptual tools that have been used in this research, section 4.1 and section 4.2 introduce the key conceptual tools from both approaches in their original context. It is worth noting that there are some detailed aspects of the conceptual tools that are difficult to explain without the empirical context, so, I briefly indicate some of them below and expand on this in the empirical chapters. At the end of this chapter, I highlight the strengths of using this theoretical framework to investigate the case of OPHC.

4.1 The socio-technical perspective of Transition Studies

I would like to start by introducing the social-technological perspective of Transition Studies. The social-technological perspective of Transition Studies is one school of Transition Studies. What is Transition Studies? Transition Studies was born in response to persistent problems in contemporary society, such as climate change, the loss of biodiversity, and the depletion of resources (e.g. oil, water, food) (Geels, 2011: 24). These problems are often expressed as crises. Transition Studies posits that these crises are generated through processes that are embedded in the social structure and they often reflect dominant patterns of socio-technological development which are difficult to resolve. So, in order to address these problems, Transition Studies suggests that deep structural change is needed. This not only requires technological change but also an overall *configuration* of a system of elements, such as regulation, markets, user behaviour, and cultural meaning (Elzen et al., 2004; Geels, 2011; Smith et al., 2005).

Transition Studies is an umbrella term that holds the above attitude of socio-technical change. It has three ‘schools’ (Grin et al., 2010): *socio-technical transition* (Geels and Schot, 2010), *transition management* (Loorbach and Rotmans, 2010), and *governance perspective* (Grin, 2010). *Socio-technical transition* is based on historical cases of already completed transition in areas such as transportation, energy and, sewer systems. Studies look at how technological artefacts were developed and diffused in society (Darnhofer, 2015). Famous examples include how sail boats were replaced by steamships (Geels, 2002) and how the automobile replaced the horse-drawn carriage (Geels, 2005b). Through analysis of these historical cases, researchers have built theories about how transition comes into being (Lawhon and Murphy, 2011; Twomey and Gaziulusoy, 2014; Darnhofer, 2015). *Transition management* and *governance perspective* represent more recent transition research. Both approaches aim to steer transition towards a more sustainable direction (Darnhofer, 2015; Lawhon and Murphy, 2011). The three transition approaches share some core conceptual notions, such as *co-evolution*, *multi-level perspective*, *multi-phases perspective*, and *learning*. Both the *socio-technical transition* and *transition management* approaches attempt to conceptualise the underlying transition patterns and mechanisms. They translate those conceptualisations into a more management approach to guide the innovation process, such as Strategic Niche Management (SNM) (Kemp et al., 1998; Raven and Geels, 2010) and Transition Management (TM) (Loorbach, 2007 and Loorbach, 2010). Considering the purpose of this research is to understand the innovation process of a local smart city project (OPHC) rather than steering the smart city innovation in a desirable direction. I identified the *socio-technical transition* approach as the most suitable for this objective among the three transition approaches.

The socio-technical perspective of Transition Studies focuses on studying innovation processes that lead to a fundamental shift in a socio-technical system (Markard et al., 2012). It borrows insights from many distinct yet related disciplines, such as Science and Technology Studies, Evolutionary Economies, and Sociology (Lawhon and Murphy, 2011). Grin et al. (2010) summarise several key characteristics of *socio-technical transition* (Grin et al., 2010; Coenen et al., 2012). First, transitions are regarded as *co-evolution* processes which require overall *configuration* of technology, policy, markets, cultural meaning, and so forth. This reflects a contextual way of understanding technology. It is inspired by Science and Technology Studies (STS). STS understands technology development as *heterogeneous engineering* (Law, 1987). It regards technological development as a process of creating linkages between heterogeneous elements. In other words, technology itself does not have power. It has power only if it aligns with human agency. Hughes (1987) coins the term 'seamless web' to describe the combination of heterogeneous elements in achieving functionalities. In the same vein, Rip and Kemp (1989) define technology development as "*configurations that work*". A "*configuration*" refers to the alignment of heterogenous elements and "*that work*" indicates that the alignments fulfil a function. Together the phrase means the alignment of heterogeneous elements that are stabilised to fulfil a function (Geels, 2002). Second, *socio-technical transition* regards transition as a multi-actor process which involves interactions between different social groups with different interests, capabilities and roles, such as scientific communities, businesses, policy makers, and special interest groups. Third, it regards transition as a radical transformation. This does not necessarily mean the speed of change, but it indicates the change from one social-technical *configuration* to another. Fourth, it regards transition as a long-term process which usually unfolds in the course of 20+ years (Coenen et al. 2010). The OPHC case fits the first three characteristics of the socio-technical perspective of Transition Studies, for example, it is a novel *social-technical configuration* that involves multiple actors and has ambitions to bring transition change to current urban development and the communication network industry. However, due to time constraints, the research only observed the early transition process. This does not mean that the socio-technical transition approach is not suitable for this research. It still provides rich theoretical insights to understand the micro innovation process that were embedded in the broader and longer socio-technical context. Its analytic tool Multi-Level Perceptive (MLP) especially helps to analyse the structure that OPHC smart city innovation is imbedded in. Its analytic tool Strategic Niche Management (SNM) contributes to understanding the innovation process of OPHC in detail. At the time of writing, there were several examples of using MLP and SNM in studying smart cities projects. For example, Carvalho (2014) applied MLP and SNM to study the processes of two paradigmatic 'smart city' cases (Songdo and PlanIT Valley). Valdez et al., (2017) use SNM to study a smart transportation application called Motion Map in Milton Keynes (UK). Below, I introduce the analytical tools of Multi-level perspective (MLP) and Strategic Niche Management (SNM) in detail.

4.1.1 Multi-level perspective (MLP)

(1) The intellectual sources of the MLP

Multi-level perspective (MLP) is the core of socio-technical Transition Studies. It originated with a group of researchers who sought to bridge Science and Technology Studies (STS) and Evolutionary Economics (EE) (Rip and Kemp, 1998; Schot, 1998; Geels, 2005a). It combines concepts from Evolutionary Economics (*niche, regime, speciation, path dependence*), Science and Technology Studies, Structural Theory, and Neo-Institutional Theory (structure is both context and outcome of actions). Although they have different roots, their understanding of the process of technological change are very similar (Grin, 2010: 30).

MLP creatively assembles the best elements from four sources into a coherent framework and avoids the weaknesses of each approach. For example, MLP takes from STS its sensibilities of paying attention to complexity, fluidity, alignment, linkages, contingency, and agency in technological change. Informed by ANT's concept of *heterogeneous engineering*, each level of MLP is regarded as a *heterogeneous socio-technical configuration.* However, ANT has its weaknesses. One issue is that it is overly focused on a heroic storyline, which neglects the wider structure that an innovation is embedded in (Grin, 2010: 33). For example, Callon's classic electronic car case, follows how different actors work together to produce an electronic car. When things go wrong, actors just create new alignments. This approach neglects other elements in the innovation process, such as expectations, learning, experimentation, and so on. Another issue of STS or ANT is that they focus on studying short term topics and neglect long term patterns and macro-dynamics. MLP incorporates Evolutionary Economics to address some of STS's weaknesses. For example, Evolutionary Economics provides useful insights in explaining macro topics because it regards innovation as an interaction between *species* and its *selection environment*. Its concept *technological regime* can also complement STS by providing more structural embeddedness of actors. Influenced by Evolutionary Economics, MLP suggests alignment between levels have evolutionary characteristics. *Niches* are places to generate radical novelty (*variation*). Radical innovation often emerges outside existing *regimes* and needs a protected space (*niche*). The selection and diffusion of innovation depends on its alignment with *regime* and *landscape* (Grin et al., 2010). MLP also incorporates Structural Theory and Neo-Institution Theory to complement STS's lack of structure by explicitly conceptualising the structural embeddedness of actors. It contributes to differentiation at each level of MLP according to its stability and size. For example, at the *niche* level, a social network is small and unstable. While at the social-technical level, the social network is larger and heterogeneous elements (e.g. artefacts, regulations, markets, and infrastructure) are configured into a more stable structure. It also enriches Evolutionary Economics' concept of *regime* by expanding the dimension of *regime* beyond a merely technological angle.

(2) The three analytic levels of MLP

MLP consists of three analytical levels: the *niche* (the locus of radical innovations), the *socio-technical regime* (existing practices and rules), and the *social-technical landscape* (Rip and Kemp, 1998; Geels, 2002; Geels, 2011). The three levels are analytic concepts rather than essential categories (Lawhon and Murphy, 2011). They are based on the assumption that alignment within levels and between levels will produce transition. The relationship between the three levels can be understood as nested hierarchy. Geels (2002) illustrates this nested hierarchy in **Figure 13**.

The meso-level of the hierarchy is *socio-technical regimes*[7]. *Regime* contains three types of rules: *cognitive, regulative* and *normative* (Geels, 2005). Examples of *cognitive rules* are belief systems, agendas, and search heuristics. Examples of *regulative rules* are standards, laws, and regulations. Examples of *normative rules* are values and behavioural norms. The rules of the *social-technical regime* account for the stability and lock-in of a socio-technical system. Therefore, the existing *socio-technological regime* is stable. Innovation occurs in an incremental nature which leads to cumulative technological trajectories (Grin et al., 2010). The trajectory is not only restricted to the technological aspect alone, but also refers to other aspects, such as science, politics, markets, user preference, and cultural meanings. These different dimensions are regarded as different dimensions of regimes which have the potential to create tension within the existing *regime*.

The micro-level is formed by *socio-technological niches*, a protected space where novelty can emerge and grow. *Niches* are considered crucial for Transition Studies. This is because novelties are often quite crude in the early stage, so they need protected spaces (*niches*) to

[7] The concept socio-technical regime is built upon the concept of technological regimes, but it is broader than the latter by going beyond merely the technological regime and including other social groups.

shield them from mainstream market selections. A network of actors (e.g. entrepreneurs, start-ups, spin-offs) dedicatedly invest their resources in new technologies. *Technological niches* are carried out by experimental projects which are exposed to the *selection environment* gradually. Actors who work on radical innovations hope their novelties will replace the existing *regime* one day. *Niches* provide spaces for learning. Innovators not only learn about the technological aspects of an innovation, but also other aspects such as user preferences, production systems, and symbolic meanings. *Niches* also provide a space for innovators to build social networks to support innovations (Geels, 2005). The creation and enactment of *niches* is explicitly addressed in the Strategic Niche Management (SNM) literature which I will expand on later.

The macro-level is formed by the *socio-technical landscape*. The *socio-technical landscape* is a long-term exogenous trend that influences *regimes* and *niches*, such as demographic trends, climate change, urbanisation. The metaphor of *landscape* is chosen due to its connotation of "*hardness*" and "*materiality*" in the context of society (Geels, 2002). *Socio-technical landscape* is an external context of *regime* and *niche*. It goes beyond the direct influence of the individual and cannot change in the short run (Geels, 2005). However, there are two types of change at *landscape* level. One is slow change such as cultural or demographic change. The other is more rapid, even shock change, such as oil prices changes or economic depression.

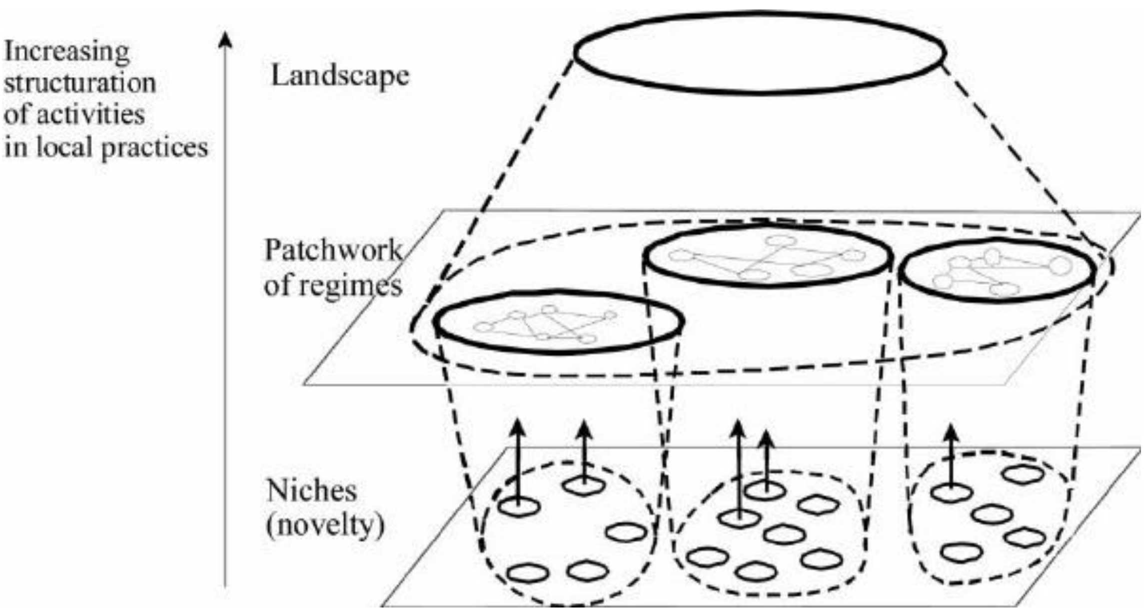


Figure 13. *Multiple levels as a nested hierarchy (Geels, 2002: 1261)*

(3) Mechanisms of MLP transition

MLP regards transition as a result of ongoing interaction and *co-evolution* between the three levels. Transition is not a linear process and there is not a simple force that drives the transition. Each transition is different, but there are some general patterns; a) internal momentum builds up in a *niche*. b) changes at *landscape* level create pressures on *regime*. c) destabilisation of *regime* creates *windows of opportunity* for niche innovations (Geels, 2011: 29). Geels (2002) made a representation of this ideal transition (shown in **Figure 14**) which has somewhat become the standard picture of this dynamic. As we can see in **Figure 14**, there are many small arrows at *niche* level which go in different directions. They represent novelties emerging in the *niche* in the context of existing *regime* and *landscape* because novelties are not stable at the beginning of an innovation. They may compete with other designs and innovators have to figure out the best design through experiment. Although a novelty is promising, it will remain in a *niche* for a while. There are several reasons. First, it takes time to troubleshoot (Grin et al, 2010). Second, radical innovation may be a mismatch with the existing *regime*, such as infrastructure, policies, and user experience. Third, the existing *regime* might be explicitly against the novel innovation. In this case, the *niche* innovation will find it hard to have a breakthrough as long as the *regime* remains stable.

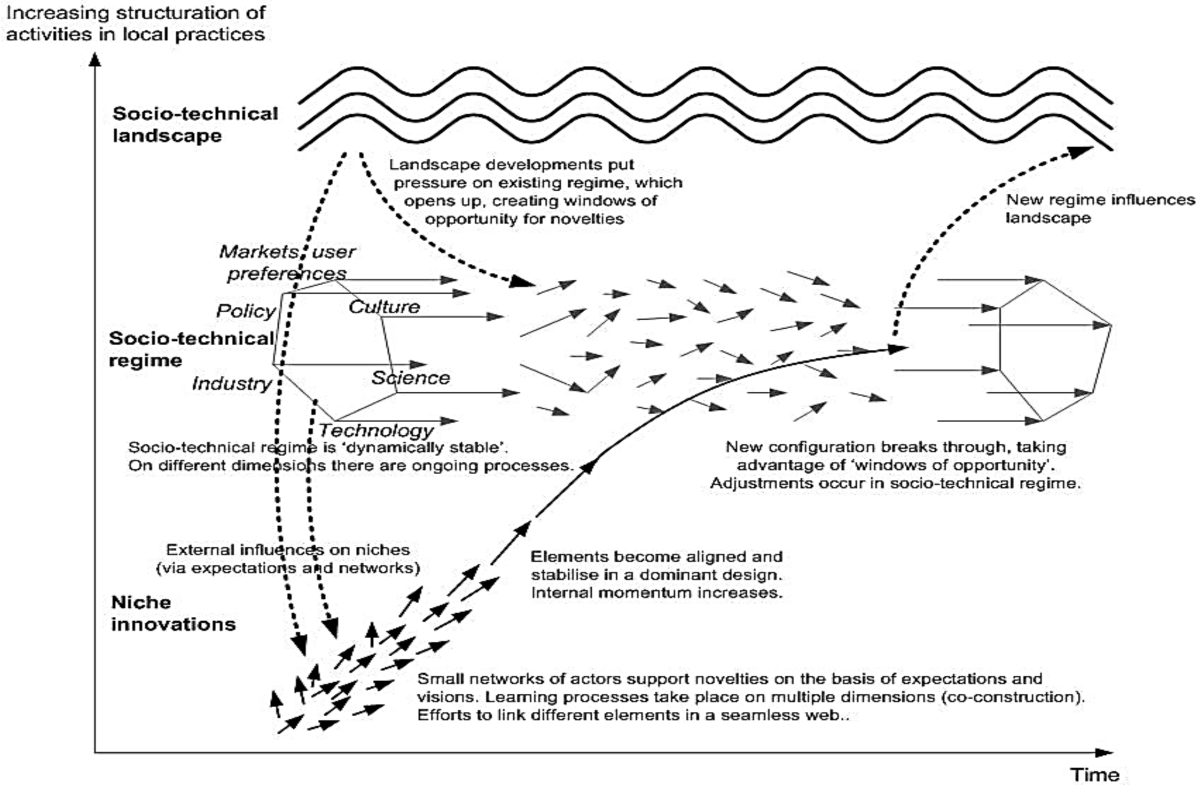


Figure 14. *Multi-level perspective on transition (Adopted from Geels, 2002: 1263)*

New technology gradually improves as a result of a learning process. For example, it might stabilise in terms of design and articulated user experiences. As we can see in **Figure 14**, Geels uses longer and fatter arrows to represent stabilised novelties. The wider breakthrough of the niche innovation depends on changes at the *landscape* level. But, changes at *landscape* level usually happen slowly. Geels (2002) uses fat long arrows (**Figure 14**) to illustrate the stability at *landscape* level. The *landscape* might create pressures and tensions to the existing *regime* (vertical dotted arrows). This may result in a *window of opportunity* for the *niche* innovation. In the end, the *niche* innovation might diffuse to the market and succeed over the competition. This might eventually lead to wider *socio-technological regime* change.

(4) Criticisms of MLP

There are some criticisms of the multi-level perspective of the *socio-technical transition*. First, geographers criticise MLP for its lack of sensitivity of spatialities, scales, and places. They argue that the three levels in MLP are not geographic levels. Current MLP assumes that country and nation are the key context in which *niche* and *regime* are situated. However, this way of thinking lacks understanding of how local conditions contribute to the emergence of a particular innovation. In response to this criticism, some scholars are seeking to develop a second generation MLP called the multi-scalar MLP perspective. For example, Raven et al.(2012) have explored Multi-level perspective at spatial level. Coenen et al. (2012) have studied the geographic unevenness of transition processes. Senger and Raven (2015) have traced how Rapid Bus Transit has spread from South America to Bangkok. In relation to the role of the city in MLP, Huston and Marvin (2009) have explored the role of city and region in the *socio-technical transition*. Lawhon and Murphy (2011) have argued that there are many transition case studies conducted in a European context (e.g. Netherlands) and there is a need to include more cases from global south. I will elaborate on the lack of spatialities in the next section. Second, MLP is criticised because of the lack of agency in transition. Smith et al. (2005) have argued MLP is too descriptive and structural which leaves little room for studying agency. In response to this, Geels (2011) has argued that although MLP does not explicitly show agency, the alignments at each level and trajectory are actually always enacted by social groups. It accommodates agency such as bonded rationality and interpretive activities. However, it is true that other types of agency (e.g. power struggle) are less developed in MLP. There have been some attempts to incorporate other types of agency in MLP, such as power, social movement, and the cultural dimension (Grin et al., 2010;

Elzen et al., 2004; Geels and Verhees, 2011). Third, the bottom up change model of MLP has been criticised for bias because it tends to believe that *regime* change begins with *niches*. To counter this bias, Geels and Schot (2007) identified four transition pathways. Since this research only focuses on the earlier transition phase, I will not go into detail about this. For more on this, please see Grin et al. (2010).

4.1.2 Strategic Niche Management (SNM)

MLP conceptualises the underlying patterns of transition and those conceptions are translated into the management approach: Strategic Niche Management (SNM). The term SNM was first labelled by Rip (Schot, 1992). It was later adopted by Schot et al. (1994) and Kemp et al. (1998). The birth of SNM started from the questions: "*why do many promising sustainable technology innovations always end up in R&D Laboratories or as demonstration projections? Why it is so difficult for them to move to the market or spread widely in real life?"* SNM was created to answer these questions. The core assumption of SNM is that a sustainable innovation journey can be facilitated through creating a technological niche. A technological niche is a protected space to allow the nurture and experiment with *co-evolution* of technology, user practices, and regulatory structures (Schot and Geel, 2008: 538).

The technological *niche* often involves policy makers. They subsidise *niches* to develop 'not-yet' profitable technology because they believe niche innovations can become important for society in the future. However, this does not mean SNM is created by government in a top-down approach. Instead, it emerges through collective enactment or what SNM scholars call "*steering from within*" (Grin et al., 2010: 80). People who steer SNM do not necessarily have to be policy makers, they can also be users and others societal groups. The steering process can fulfil many development goals. For example, it can expand the social network of the innovation. It can fulfil specific learning. It can also carry out a series of demonstration projects to find a desirable pathway. Below, I review three aspects of SNM which are considered relevant to this research.

(1) Three niche internal processes

Early SNM research believed that novel innovation needed to be developed in a protected space (*niche*), within which novel innovations could be selectively exposed to the market through a niche development process. This process might eventually transform or replace the dominant technologies in the existing regime. In response to the question, how does the process happen in reality? Kemp et al. (1998) and Schot and Geels (2008) drew on insights from STS, Evolutionary Economics, and the history of technology, to develop three niche mechanisms that contribute to successfully developing a *niche*: (a) *articulation of expectations/visions*, (b) *building social networks*, and (c) *learning*.

a) The *articulation of expectations/visions* is considered as a crucial mechanism for niche development, especially in the earlier stage of an innovation where nothing is solid. The *articulation of expectations* can nurture niche development through attracting attention and resources. It also provides direction for learning and research. Hoogma et al. (2002) argue that if visions are robust (shared by many people) or they are high quality (manifested in an ongoing project), this will make the vision easier to articulate. Schot and Geels (2008) have argued that the proposed expectation should leave a certain degree of *interpretation flexibility* (See more in Chapter 7) for people. If the expectation is too general, it will lose its function of guidance. It is too narrow, it will not encourage people to participate. The Sociology of Expectation has also studied the *articulation of expectation* as part of its argument that vision is performative (see more in the next section). SOE highlights some elements that affect the *articulation of expectation*. For example, Van Lente (1993) argued that the *articulation of expectation* through *words* should not contradict *readable actions* (See more in Chapter 6). Otherwise, it will affect the articulation *of expectation*. Konrad (2006) studied private expectation and collective expectation, and has argued that collective expectation sometimes causes *image pressure* (See more in Chapter 6) for people to take up an expectation which they have no specific interest in. Berkhout (2006) found visions of future tend to be moralised and might make people buy-in. I expand on both these insights in Chapter 6.

b) *Building social networks* around new technology is considered another important mechanism for *niche* development. It can facilitate interactions between different stakeholders and attract necessary resources (money, people, skills) around new technologies. The quality of social networks will influence niche development. Broad social networks which involve many stakeholders and views will enhance the *articulation of expectations* to broader audiences. Deep social networks where people represent their organisations can also be beneficial for niche development. Because those actors can mobilise commitments and resources in their organisations.

c) *Learning* is another key element for *niche* development. It can happen in multiple dimensions, including the areas of techniques, markets, user preferences, cultural and symbolic meanings, infrastructures, industries, regulations, societal and environmental impacts (Hoogma, 2000; Schot and Geels, 2008: 540; Raven, 2005). Hoogma (2000: 58) further distinguishes between *first-order learning* and *second-order learning*. *First-order learning* refers to accumulated facts and data to verify pre-established goals. While *second-order learning* indicates learning that changes the initial cognitive frames and underlying assumptions.

The three niche internal process hypotheses have been tested through an EU project and three PhD theses (Hoogma, 2000; Van Mierlo, 2002, and Raven, 2005). The three niche internal processes have been applied to cases to explain the success or failure of a project (Schot and Geels, 2008). The empirical cases have generated many recurring findings. For example, many demonstration projects tend to have a narrow social network and are overly focused on *first-order learning*. In those projects, users have often been regarded as consumers with pre-assumed needs. This is reflected in the way that most of the demonstration projects have sought to discover the mismatch between technological features and assumed needs. Some of those findings have also identified shortcomings of SNM. For instance, many demonstration projects have focused overly on experiment with technologies. The involvement of outside actors and *secondary order learning* never happens easily.

(2) Local niche and Global niche

The niche internal process established earlier thinking about how novelty moves from a *technological niche* to the market, and eventually changes the *regime*. The idea is that a *niche* is a protected space that can help the novelty to develop. Niche internal processes help the novelty to build up a protected space to experiment, learn, and mature. When the novelty is ready to be exposed to a harsher environment, innovators gradually reduce the protection. Then, the novelty is expected to replace the old *regime*. Raven (2005) and Van Mierlo (2002) made a crucial contribution to further develop this model. They argue that a *technological* *niche* is not merely characterised by protection, but also by locality and instability. The core of their argument is that a niche development can be understood as a process at two levels (the local and global level) simultaneously. Geels and Raven (2006) illustrate the distinction between the local and global level in **Figure 15**. As we can see from figure, there is a network of actors who carry out several projects at the local level. While at the global level, there are emerging stabilised rules. The separation between *local niche* and *global niche* was inspired by Actor-Network Theory. ANT theorists had made the distinction between local and global networks (Law and Callon, 1992). For them, the local network refers to heterogeneous human and non-human actors that are related to the project. Whilst the global network are actors who hold a certain distance to the project but could provide resources, finances, workforce, and technical support to the project. Geels and Raven (2006) rephrase the definition of local and global networks. They argue that local actors are people directly involved in a project, while global actors refer to an emerging field of community.

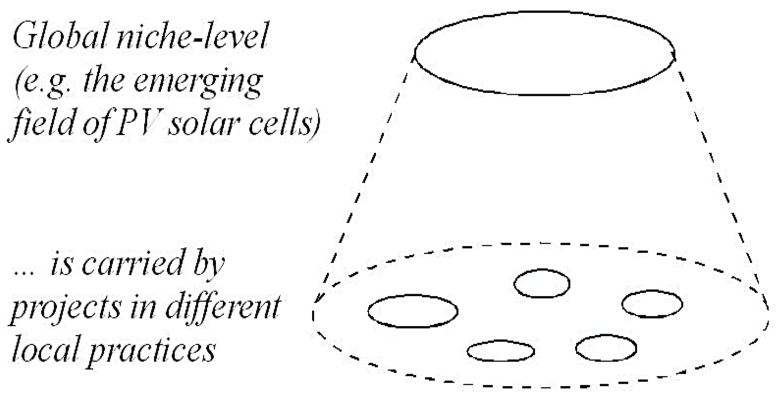


Figure 15. *Local niche level and global niche level (Adopted from Geels and Raven, 2006: 378)*

Geels and Raven (2006) develop the parallel local and global niche development model in **Figure 16**. As the figure shows, there are many concrete projects that happen at the same time at a local level when an innovation is in the early stage. Place specific actor networks generate place specific knowledge. They are carried by local actors and networks for local or idiosyncratic reasons. At a global level, the cognitive rules at this stage are diffuse and unstable. So, Geels and Raven (2006) use dotted lines to represent the unstable nature of rules in the figure. As time goes by, projects at local level build on each other for a sequence of time. Novel ideas are put into testing in local projects and generate many lessons. The local lessons distil and contribute to stable rule formation at the global level. Eventually a sequence of local projects adds up to a technical trajectory at the global level. The cognitive rules at the global level become more articulated, specific, and stable. The separation between *local niche* and *global niche* bring new insights in niche development. It shifts our attention from looking at the success and failure of a particular project to looking at a series of projects. It also shows how a sequence of projects contributes to shared rules at the global level.

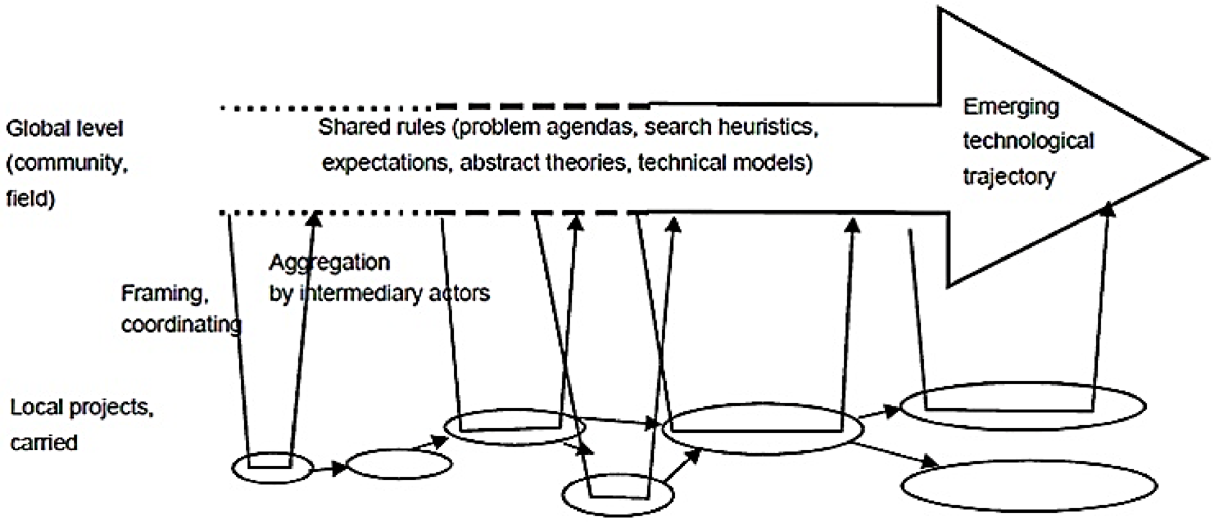


Figure 16. *Emerging technical trajectory carried by local projects (Adopted from Geels and Raven, 2006: 379)*

The formation and stabilisation of the *global niche* is a process of accumulating local knowledge. Deuten (2003) and Geels and Raven (2006) regard this as a process of *aggregation.* What is *aggregation*? According to Geels and Deuten (2006: 266-267), *aggregation* is "*a process of transforming local knowledge into robust knowledge, which is sufficiently general, abstracted and packaged, so that it is no longer tied to specific contexts*". This concept was originally generated from the question of "*how knowledge can actually flow".* Deuten (2003) argues that local knowledge diffusion to a global scale is the first step for knowledge to flow. Lessons from local practices do not flow to other locations directly. Knowledge should be context-free before putting it into circulation (Geels and Deuten, 2006). This argument echoes lab studies which find that scientists in labs always want to find a way to make knowledge production in one lab work in another lab or outside the lab in a real-life context (Rouse, 1987; Latour, 2000). SNM scholars argue that lessons learned at *local niche level* need to go through a process of *aggregation* to spread to the *global niche* level. The *aggregation* activities can help global actors to compare local practices and distil global generic lessons. There are several typical *aggregation* activities, including standardisations, codifications, model building, and the formation of best practices (Geels and Deuten, 2006: 267). Conferences, seminars, workshops, journals and news coverage, are regarded as infrastructures for *aggregation*. Those infrastructures are important for aggregating activities because they help to communicate and compare local practices.

Actors in *local niches* often take up roles to promote aggregation. They aggregate local practices through presenting and attending conferences, workshops, and seminars. Apart from niche actors, *intermediary actors* are another group of actors who aggregate local practices to the global level (Geels and Deuten, 2006). *Intermediary actors* are actors such as standardisation organisations, professional societies, industry associations, and firms. They monitor multiple local projects, perform the role of *aggregation*, and help to circulate local knowledge (Schot and Geels, 2008). *Intermediary actors* are considered important in *aggregation* processes because the knowledge production at the local level is a collective good. It might be used by people who are not involved in the production. *Intermediary actors* (e.g. standardisation organisation and industry association) can help to avoid free-riding. Van Lente et al. (2003) further argue that there is a new type of intermediary organisation which plays an important role in technological transition. They call it the *systematic intermediary*. The reason for this label is because traditional *intermediary actors* just work at a one-to-one level of interaction, while *systematic intermediary* actors work at a system or network level. According to Van Lente et al. (2003), *systematic intermediary actors* include knowledge intensive business services, research and technology organisations, industry associations, chambers of commerce, innovation centres, and university liaison offices. They broker relations between different parties.

(3) The spatial dimension of the niche

Going beyond the local and global niche models, geographers argue that the model lacks a proper dimension of space (Sengers and Raven, 2015). The words “local” and “global” would seem to have spatial connections, but in fact they have a narrow understanding of space. For example, the *niche* can often be seen as a national or local entity. Sengers and Raven (2015) argue exploring the spatial dimension of *niche* matters. They highlight two advantages of adding the question "where" to SNM. First, it brings us more insights about why niches emerge in a particular place. As Raven et al., (2012: 67) argue that, "*niche development is not determined only by the development of actor networks, expectations, and learning, but also by the specification of the place and uneven endowments and access to innovation capabilities and resources*". To provide examples for this argument, Sengers and Raven (2015) observed that *niches* are more likely to emerge in settings where the relational assets are needed for radical innovations. Second, to add a spatial dimension to the simple local and global niche model can help enrich our understanding about the global diffusion of niche innovations. At the moment, we have little knowledge about how *local niche* travel beyond territories and whether they have been successful or failed to entangle in place specific power relations, institutions, and infrastructures (Sengers and Raven, 2015: 168). A spatial *niche* development could provide us with insights about the process of how a *global niche* innovation can became embedded in a specific local context.

There is some pioneering research in the area of *niche* spatial development (Coenen et al., 2012) and Sengers and Raven, 2015). For example, Sengers and Raven (2015) reviewed three geography literatures to seek to understand how those literatures can enrich the understanding of core SNM processes. The first group of literature is around the "local buzz and global pipelines argument". The idea is that vibrant information (buzz) interacts and exchanges at the local level. Actors with shared values in a local context build a "pipeline" to communicate and harness external knowledge. Coenen et al, (2012) argue that the "local buzz and global pipelines argument" contributes to understanding learning processes in *niche* spatial development. The exchange of codified knowledge and lessons requires actors to build communication channels. However, successful communication requires not only communication challenge, but also different levels of *proximity*. I will come back to this point later. The second group of literature is that of global production networks (GPN). This type of literature looks at economic globalisation and its development consequences in relation to specific production. Coenen et al, (2012) argue that GPN contributes to spatial niche development in terms of *building social networks*. They suggest treating actors as anchored in different institutions and geographical environments. Together they form networks of actors across the global. These linked networks are power geometries which shape the niche building. The third type of literature is that of policy mobilities. This emphasises the role of the city as an important global node for knowledge exchange. Coenen et al. (2012) especially pay attention to a type of actor called a 'transfer agent' in the exchange process. They are the knowledge workers such as urban planners, travelling technocrats, architects, and global consultancies. “Transfer agents” are important for spatial niche development because they help to articulate niche expectations to another context. Therefore, Coenen et al. (2012) suggest researchers should follow niche actors in their travels and examine how the story is told in their discourses.

These three geography literatures are complementary with each other, in a way they all consider local and global interaction, trying to understand local networks of actors, knowledge circulation and embedded processes. But, they have different areas of focus. The “local buzz and global pipelines” approach starts with one place and investigates how it is connected with its distribution place. While, the other two approaches are either focused on the international diffusion network or the diffusion agents. In order to analyse the diffusion process of OPHC, I focus on the “local buzz and global pipelines” approach because it helps to understand how a local niche diffuses to another niche (Chapter 7). Within this approach, Boschma’s (2005) concept of *proximity* has been adopted to understand niche development in the spatial sense. Coenen et al. (2010: 168) point out that the concept of *proximity* (Boscham, 2005) can specifically enrich the local and global niche model in relation to the questions of upscaling an innovation. The concept of *proximity* was coined by Boschma (2005) based on his study about the relationship between the local context and innovation process. He distinguished five different types of *proximity*: *cognitive-*, *organisational-*, *social-*, *institutional-*, *and geographical- proximity*. *Cognitive proximity* refers to shared knowledge that enables communication, understanding, absorption, and successfully processing new information. *Organisational proximity* means a set of interdependencies within and between organisations. *Social proximity* is socially embedded relations between agents at a micro-level. It often involves trust based friendship, kinship, and experience. *Institutional proximity* is about institutional rules of the game, a set of cultural habits and values shared by economic actors. *Geographic proximity* is defined as a spatial or physical distance between actors (Boschma, 2005). Boschma also explains in detail why too much and too little *proximity* is harmful for interactive learning and innovation. Coenen et al. (2010) take the *proximity* dimension in niche seriously and have conducted a case study about the Netherlands’s Aquifer Thermal Energy Storage. They integrated *proximity* in three niche internal processes (*voicing expectation*, *building social networks*, and *learning*). Their research has generated many interesting findings, for example, the *articulation of expectation* requires *cognitive* and *social proximity*. *Geographic proximity* may help facilitate the articulation process because it allows an interactive articulation process. But too strong local networks cause difficulties to upscaling experiments. *Organisational proximity* and *social proximity* are considered primarily relevant to *building social networks*. And too much *social proximity* might affect *second-order learning*.

4.2 The Sociology of Expectation

Vision and expectation have a role to play in a socio-technical innovation process, especially in the early stages of an innovation where imaginations often pre-exist before the reality. Transition Studies briefly addresses functions of vision. Especially in Strategic Niche Management (SNM) where it highlights the *articulation of expectation* as one of three niche internal processes. The role of expectation is supposed to guide the learning processes, attract attention, and provide protection for *niches* (Geels and Raven, 2006). However, Transition Studies' understanding of expectation/vision is not enough to interpret the role of vision/expectation in the story of OPHC. Because it does not provide answers for how expectations in technological innovation are structured. How does vision/expectation influence the innovation process and how does vision influence various actors' (e.g. businessmen, researchers, policy makers) decision making and agenda building?

To complement Transition Studies' insufficient understanding of the role of vision in an innovation process, I draw on conceptual tools from the Sociology of Expectation (SOE). SOE analyses expectations and their role in emerging science and technology. Van Lente is a pioneer in the field and he defines SOE as follows, "*sociology of expectation studies how expectations in science and technology are structured, how they grow, gain dramatic attention or quietly disappear, and how this affects the decisions of engineers, businesses and governments*" (Van Lente, 2012: 772). The Sociology of Expectation (SOE) builds upon a number approaches, including Sociology of Technology, science, history, economics, and Innovation Studies (Borup et al., 2006). SOE argues that future orientation plays a crucial role in science and technology innovation development. It mediates boundaries between different time, scale, communities, and levels. According to Budde (2015: 23), "*sociology of expectation can be interpreted as a term summarizing several approaches dealing with the role of expectations in science and technology, emphasizing the role of expectations have for the guidance and coordination of different actor and actor groups*". The term *expectation* indicates a state of looking forward. While *technological expectation* means real-time future representations of future technological situations (Borup et al., 2006). SOE provides a wide range of research about vision/expectation in the innovation process. It is worth noting that Transition Studies and the Sociology of Expectation are not two independent literature resources. Both literatures are based on some shared theoretical roots, including Science and Technology Studies, Evolutionary Economics, and Innovation Studies (Budde, 2015: 18). Also, the understanding of expectation in the Strategic Niche Management are directly influenced by the Sociology of Expectation literatures. Below, I review the conceptual tools from SOE. They cover various aspects of expectation/vision which are considered useful for this research.

4.2.1 The performative role of expectation

Expectations are statements about the future. A central argument in the Sociology of Expectation is that expectations are not merely statements describing future realities, instead expectations are performative in nature: they do something (Michael, 2000). As Borup et al. (2006) argue "*expectation is wishful enactments of a desirable future*". Below, I review several key concepts, mechanisms, and forces of the central argument that expectations are performative.

(1) The Prospective Structure

Van Lente and Rip (1998) contribute a key concept to the performative role of expectation which is *prospective structure*. They regard expectation of future as a 'not-yet structure' and this 'not-yet structure' has a similar influence as if it had materialised in the real world (Borup et al., 2006). To emphasise this, they coin the paradoxical term, *prospective structure* (Van Lente and Rip, 1998). According to their definition, "*a prospective structure is made up of links which can appear in texts. In the subsequent actions and reactions, the structure is filled in, modified, reshuffled, and becomes social structure*" (Van Lente and Rip, 1998: 203). In another words, a structure can be merely prospective, but still be influential.

In order to better understand this concept, it is necessary to briefly revisit key ideas behind the concept. First, this concept was born in the context of an attempt in sociology to overcome the dualism between agency and structure. There is a long-running debate between structure and agency in the field of sociology. Functionalism focuses on the importance of structure and neglects creative actors. Interactionism acknowledges human agency and forgets the constraints of structure. Van Lente and Rip (1998), in line with a non-dualist approach, regard expectation as a mediator between actors and structure. They argue that instead of looking at the structure behind the actors, they prefer to focus on the structure that actors create before them. They call this future oriented structure, *prospective structure*. There is a dialectical relationship between actors and structure. Actors create and shape the *prospective structure*. In return, *prospective structure* provides orientation for actors (Budd et al., 2012). So, from this perspective, innovation is a result of a *co-evolution* of structure and agents, and expectation/vision is a factor that is mediated in this interaction process.

This future orientated ‘not-yet structure’ is often expressed as stories, scenarios, or statements (Van Lente and Rip, 1998). Van Lente and Rip (1998) further argue that the ‘not-yet structure’ (*prospective structure*) contains *scripts* which allocate roles for the innovator themselves, others, and (future) artefacts. The idea of *scripts* is based on the Sociology of Technology Studies, especially Actor-Network Theory. The idea is that technologists and innovators not only define the characteristics of their objects, but also the world associated with the objects. Callon (1987) prefers to call this type of technologist an ‘engineer-sociologist’. He observes that designers and engineers do not just design the features of an object, but there are also endless debates about what the object will do. Where it will be used. Whether they notice themselves doing it or not. Callon (1987) argues that engineers transform themselves into sociologists, moralists, and political scientists at the moment when they are caught up in technical questions. So, in another words, when engineers or innovators produce a vision statement (*prospective structure*), they not only describe a technology, but the whole ecosystem around it. Akrich (1992) and Latour (1992) use the term *script* to describe the heterogenous elements described by ‘engineer-sociologist’. The word *script* seeks to capture the explicit and implicit messages that innovators prescribe to the artefact. Instead of using the term *script*, Callon (1986) prefers to call it ‘socio-technical scenarios’. As he describes in his classic case, Électricité de France (EDF), engineers not only design the technological aspects of the electric car (e.g. batteries, fuel cell) but also think about the economic and political elements associated with it (Schot et al., 1994).

The ‘not-yet’ arrangements/storylines in the *prospective structure* are *scripts* made by ‘engineer-sociologists’. They are not merely descriptive statements or fictions of the future. Instead, they are *performative*: they do something. The vision statements will have an effect on readers. But this effect is not the “true” or “false” of the story. Instead, it has an effect which provides a mode of coordination for people and orients people to make efforts to realise the story (Van Lente, 2012). So, although the structure does not yet exist, it is still forceful due to the perceived implication of the projected future. Some actors might adopt the vision and actively take actions to shape the *prospective structure*. A new social order might emerge based on a sequence of actions and reactions (Ibid: 206). As Van Lente and Rip (1998) argue *scripts* are *"forceful fiction"* which "*open up space for action*" (Ibid: 225). It is worth noting, the order that emerges in reality might not be exactly as described in the *prospective structure*. This is because people may strategically take up a vision which follows their own interest (Berkhout, 2006). As a result, different actor groups *articulate expectation* according to their own interests and some of their expectations might conflict with each other (Budd et al., 2012).

(2) The promise and requirement cycle

Van Lente (1993) further explores the mechanism by which a *prospective structure* coordinates people's actions to build up agendas and take up actions to shape the actual future. Based on analysis of three historical cases (Moore's Law, Membrane technology, and HDTV), he proposed a *promise and requirement cycle* to describe the mechanism that translates promises described in vision statements into the required actions (Van Lente and Rip, 1998). **Figure 17** illustrates the process of the *promise and requirement cycle*. As we can see from the figure, an expectation of promising technology is voiced which can often be described as an opportunity (1 in **Figure 17**). The future performance of the technology is often presented as promises to attract attention (2 in **Figure 17**). The actors who have been *scripted* in the *prospective structure* are required to have some responses to the roles that are allocated to them. They might reject the role allocated for them and either protest against the role or against the nature of the expectation. If they accept the roles allocated for them, then they will start to share the expectation or as Van Lente (1993) says the "*mutual positioning of the expectation"*. Then, actors start to build an *agenda*. An *agenda* is a list of priorities that requires action (Van Lente and Bakker, 2010) (3 in **Figure 17**). Then, the expectation translates into more specific requirements, such as goals, technical specifications, and task divisions (4 in **Figure 17**). It takes time and many experiments for activities to meet the requirements (5b in **Figure 17**). This is where the important concept, *niche,* comes into being in the *promise and requirement cycle*. The *niche* provides a protected space to continue experimentation (5a in **Figure 17**). Sponsors normally make money and other resources available to a protected space (*niche*) and hope concrete activities can take place for a certain period of time (Raven, 2005).

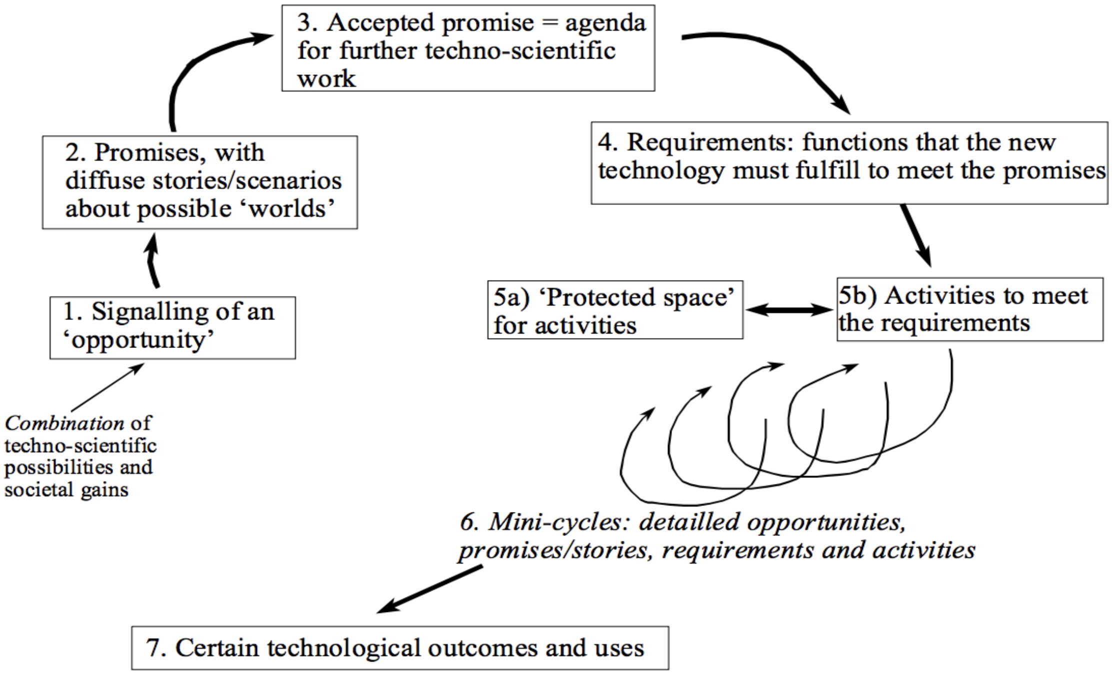


Figure 17. *Promise and requirement cycles (Adopted from Geels and Smit, 2000)*

(3) The forces of expectations

The concept of *prospective structure* suggests that a 'not-yet structure' has the potential to mobilise resources and support to 'fill in' the structure. The concept, *promise and requirement cycle,* shows how the mechanism operates in reality. Van Lenten (2012) further summarises three key forces in relation to the performativity of expectation (Van Lente, 2012).

The first force of expectation is that it helps to gain attention and legitimise investment. A novel innovation often performs crudely in the early stages. This is why Mokyr (1990) calls novel innovations 'hopeful monsters'. The reason they are 'hopeful' is because they believe in certain promising futures. They are 'monsters' because they perform crudely and cannot compete with existing technologies. So, a novel innovation itself is not convincing enough to attract investment and support. Expectation has a role to play here. It can link the novel innovation to a promising future. This linkage helps to attract necessary allies and resources for innovations. Because expectation helps to legitimise investment and support for a novel technology, so expectation is often regarded as protective of new technology. The novel innovation might have many failures before it actually delivers something in the future. Since it is associated with a promising future, it is still granted support even it remains at a stage of experiment or produces many negative results. Konrad (2006) specifically investigates the failures within the protected space. She argues that it is difficult to evaluate innovation results. As long as the collective expectation provides a protected space for the novel innovations, innovators can apply *interpretation flexibility* (see more in Chapter 7) to justify failures. For example, current failures will be interpreted as temporary. The next experiment will surely succeed (Ibid) (see more in Chapter 6).

The second force of expectation is that it provides a search direction for a scientific or technological innovation. This is especially the case in a time that there are many pathways and uncertainties in front of technology developers. Innovators have many choices and do not know which way to go. The informal expectation circulated amongst technology developers might suggest some promising directions. Expectation in this situation can reduce the uncertainty that innovators feel and function as a *heuristic device* that can guide innovators to explore certain possible future technological development directions.

The third force of expectation is *coordination*. Usually, we regard markets, hierarchies and network as models of the *coordination* in social life (Thompson et al., 1991). In an emerging technological development, there is often a lack of a central control. Van Lente (1993) and Konrad (2006) suggest that expectation or vision serves as a *co-ordination* device in the socio-technical innovation process. Technological development is not isolated work, instead it needs co-ordination from various actors, such as a network of companies, institutes, and actors. Innovators often choose certain tasks for themselves and assume other tasks will be taken up by others (Van Lente, 2012). As we can see in the mechanism of the *promise and requirement cycle*, an expectation can motivate heterogeneous actors to engage the promising technology. Van Lente and Rip (1998) have conducted historical case studies (Moore's Law, Membrane technology, and HDTV) of the coordination mechanism. They have found two different coordination mechanisms. One type of coordination is more articulated. An extreme case of this type of coordination is Moore's Law. Moore's Law is a classic case of a self-fulfilling prophecy. The prophecy of Moore's Law was fulfilled just because actors took up the prophecy and acted accordingly. In other words, the visionaries and the actors established a mutual expectation, which was realised in reality. Another type of coordination is more diffuse coordination. In the case of membrane technology, there is no problem as it requires a membrane technology to solve. Innovators of membrane technology announced a promising direction and built *agendas* gradually into the process. No matter in a more articulated situation or in a more diffused situation, the vision's coordination function describes the force to coordinate heterogeneous actors took up actions and to co-evolve with structures.

4.2.2 The hype and disappointment cycle

Expectation is performative in nature. In the early stage of an innovation, a vision of a technology can often be inflated and exaggerated in order to raise profiles and attract alliances (Borup et al., 2006). Van Lente (1993) further notes that innovators often inflate a vision in order to establish themselves as a *salient point* in a field for others to look at and follow (see more in Chapter 7). The purpose of high and rising expectation is to help mobilise the future in the present. However, exaggerated expectation is a double-edged sword. When the promise of early, high and rising expectation is hard to materialise as foreseen and the eventual technological development is not as accurate as the expectation, the expectation proves to be an overshoot and a disillusionment. This can damage reputations and trust in a project (Brown, 2003).

Sociology of Expectation scholars observe this temporal pattern of expectation over time; an emerging technology tends to start with high and rising expectations and this is likely followed by disappointment. The high and rising expectation could be regarded as *hype*. The word *hype* in public discourse often has the negative connotation; that it is deceptive and incorrectly exaggerated. However, Sociology of Expectation scholars are not interested in *hype* as accurate. Instead, they focus on how *hype* effects the activities in the present (Van Lente et al., 2013). They give a special name for this temporal pattern of expectation; the *hype and disappointment cycle* (Ibid). Actually, Sociology of Expectation scholars are not the only group of people who pay attention to the hype cycle. In the business world, Gartner Consultancy has produced a hype cycle to facilitate strategical investment decisions (Van Lente et al., 2013). Gartner's hype cycle illustrates the ups and downs in socio-technical development. As we can see in **Figure 18**, the cycle consists of five phases: "technological trigger", "expectation peak", "trough of disillusionment", "slope of enlightenment", and "plateau of productivity".

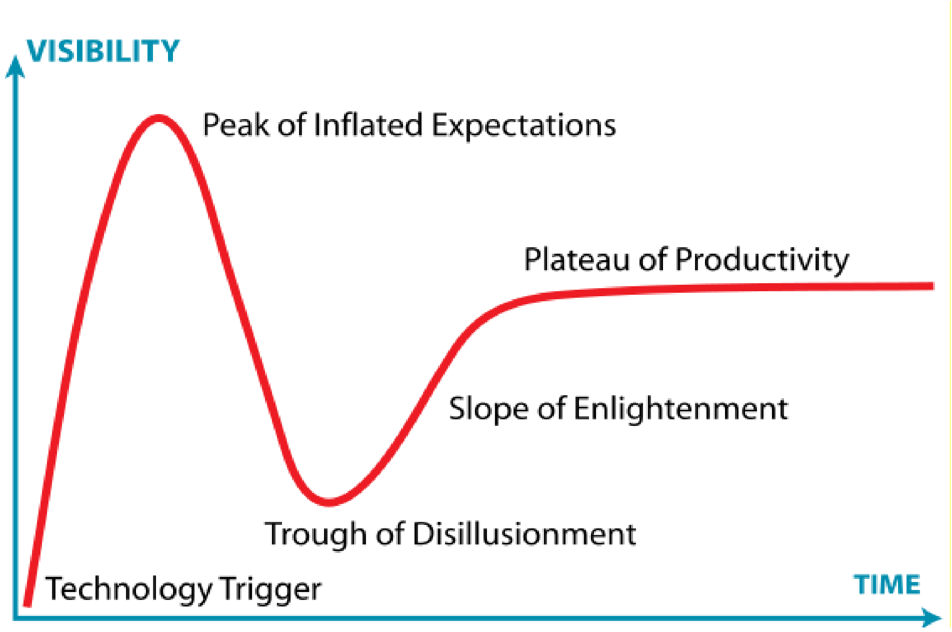


Figure 18. *Gartner Hype Cycle (cited from Wikipedia, licensed under common creative)*

However, Van Lente et al., (2013) argue that Gartner's hype model is too neat. The Gartner model shows a linear way of understanding technology development. It does not consider that technologies might reconfigure over time. Also, the Garner hype cycle may be more accurate in an established industrial environment and less useful for an emerging technology. Brown and Michael (2003) and Brown (2003) suggest that hype patterns are influenced by characteristics of an emerging technology and the environment it is associated with, such as funding and actor structures. Van Lente et al., (2013) further explore the hype patterns. Drawing on Van Lente's (1993) levels of expectations (see below), they further distinguish that hype can happen at three levels: the micro level (project level), meso level (field level), and macro level (social level). They compare the hype cycle of three cases (VoIP, gene therapy, and high-temperature superconductivity) and find that the hype cycles in these three cases resemble Gartner's hype model. But they also found greater disappointment might be experienced after hype when expectation at project, field and social level are neatly aligned (Van Lente et al., 2013: 1626). So, they suggest that some degree of misalignment between levels might turn disappointment into a productive reconfiguration of expectation (Ibid). From another starting point, Ruef and Markard (2010) also distinguish expectations at three levels: the project level, technology level and social level, to study the effects of disappointment (Budde, 2015: 26). They find that disappointment at the project level tends not to have an effect on actors' strategies, while failed expectations at the field level or social level will have an impact on actors' strategies (Budde, 2015: 27).

4.2.3 Levels of expectation

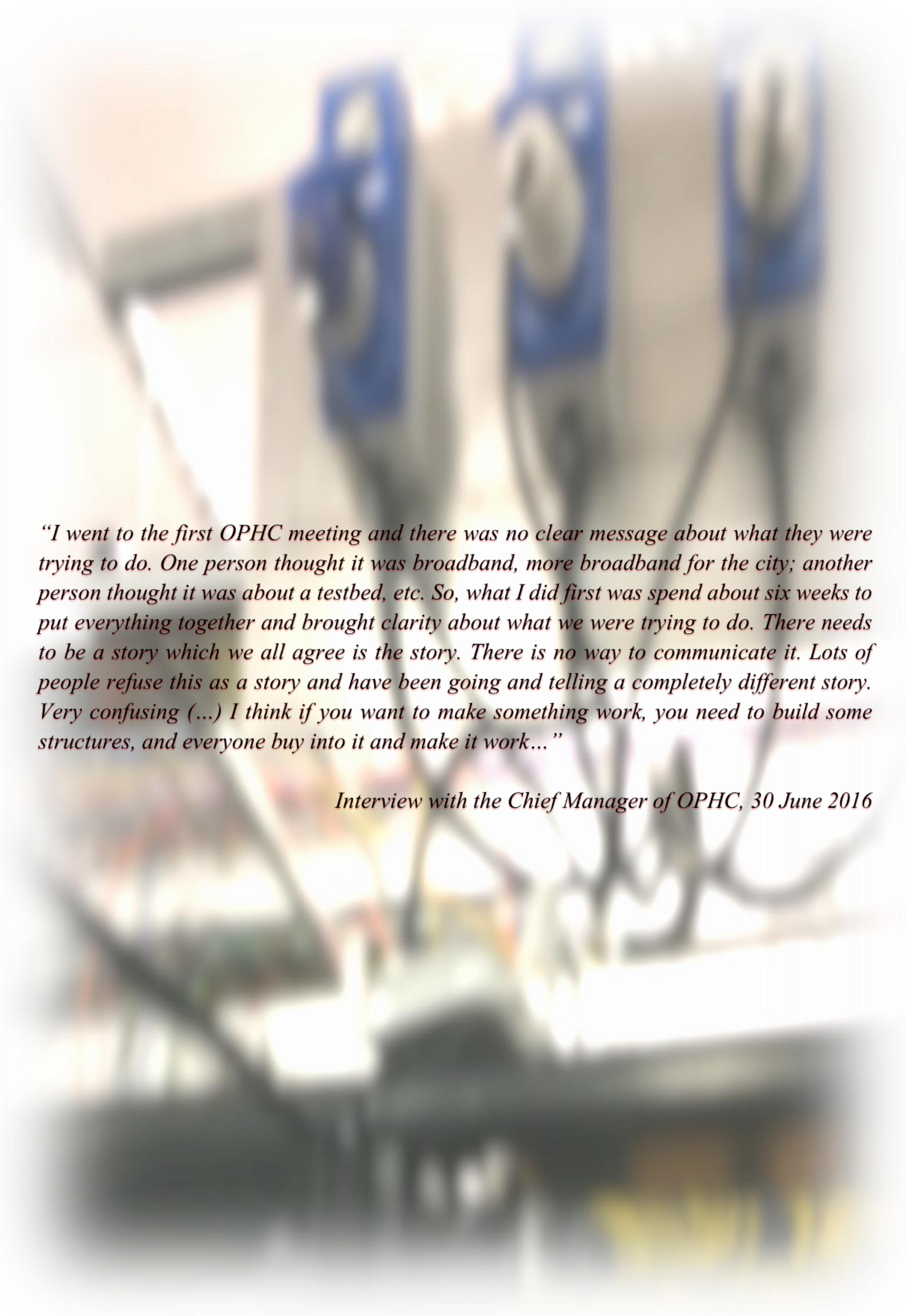
As mentioned above, expectations have many levels. Van Lente (1993) identifies levels of expectations by investigating many historical innovation cases. Similar to the Multi-level perspective, he distinguishes three levels of expectation: micro expectation, meso expectation, and macro expectation. The expectation at the micro level is an expectation of a technology in focus. It is a specific technology expectation. While expectation at a meso level is more general than the specific capability of a single technology. Expectation at the meso level often has a function to provide the criteria for the selection of technology. At the macro level, expectations are more related to broader social development. Expectation at different levels have different functions. Expectation at the micro level is likely to be taken up by research groups or firms to guide local research directions (Budde et al., 2012). Expectations at the meso level point to general opportunities and directions in a field. Expectations at the macro level legitimate a technology and open up opportunities for promising technologies. They also provide a protected space for niche developments.

Expectation at the macro level tends to influence the choice of technology at the meso and micro level. Van Lente (1993) uses the term *macro agenda* to capture clusters of expectations in relation to technology at a macro level. The original definition of a *macro agenda* can be traced back to Kingdon (1984: 3-4). He defined a *macro agenda* as *"the list of subjects or problems to which (...) people (...) are paying some serious attention at any given time. (...) Out of the set of all conceivable subjects or problems to which official could be paying attention, they do in fact seriously attend to some rather than others. So, the agenda-setting process narrows this set of conceivable subjects to the set that actually becomes the focus of attention"* (Van Lente, 1993: 166). Van Lente observed that technology might appear in a macro agenda in two ways. First, certain technologies are considered important for certain cultures at a certain time. Second, technology is a generic promise of progress. Van Lente finds that the *macro agenda* of technological progress is part of the Western industrialisation culture and there is a deep belief in technological progress in western society. In a similar vein, Geels and Smith (2000) claim that expectation may be biased by "*a broader cultural concern of the time*". Their cultural lens colours people's idea about the future (Geels, and Smith, 2000: 8). A culture may have certain anxieties and hopes at a certain historical time. The anxiety and hope is reflected in their future expectations. The anxiety and hope are also related to their memory of the past. So, it would be understandable that certain technologies can help to release certain anxieties or sustain certain hopes.

4.3 Conclusion

'Smart cities' is a subject with a growing literature, but there is no unified or best theoretical framework for this emerging phenomenon. The choice of theoretical framework should depend on the characteristics of the smart city project. Through the *iterative-inductive* process, I combined conceptual and analytical tools from the socio-technical perspective of Transition Studies and the Sociology of Expectation to form a theoretical framework for this research. Above, I have provided a detailed review of the key concepts of both approaches; MLP, SNM, the *performative role of expectation*, the *hype and disappointment cycle*, and the *levels of expectations*. This research is not the first case to use MLP and SNM to understand smart cities projects. See more in Carvalho (2014) and Valdez et al., (2017). However, it might be the first attempt to creatively assemble MLP, SNM with conceptual tools from the Sociology of Expectation to study a smart city project.

This framework is useful for this research in three ways. First, it contributes to understanding the complex innovation processes of OPHC. It not only illustrates the alignment process, but also provides explanations to various other elements in the innovation process. Second, it provides conceptual tools to understand the broader structure that OPHC is embedded in and its spatial diffusion process. Third, it provides insights into the dynamic roles vision plays in the innovation process of OPHC. In the next three empirical chapters, readers will see how this framework is useful to shed light on OPHC's emergence, implementation, and diffusion. Readers will also see the strengths of these approaches in answering the three research questions.



"I went to the first OPHC meeting and there was no clear message about what they were trying to do. One person thought it was broadband, more broadband for the city; another person thought it was about a testbed, etc. So, what I did first was spend about six weeks to put everything together and brought clarity about what we were trying to do. There needs to be a story which we all agree is the story. There is no way to communicate it. Lots of people refuse this as a story and have been going and telling a completely different story. Very confusing (…) I think if you want to make something work, you need to build some structures, and everyone buy into it and make it work…"

Interview with the Chief Manager of OPHC, 30 June 2016

Cast I

People

Brian, the Director of the DOCK
Camila, co-director of Straw House
Chris, the Chief manager of OPHC from July 2014 to June 2016.
Luke, the Manager of OPHC till 2014.
Ruby, a civil servant from Harbour City Council.
Richard, a civil servant from Harbour City Council.
Susan, the Chief Technology Designer of OPHC.
Vincent, a computer scientist from Harbour City University

Institution & company

Blue Arrow, a company in Harbour City who provide its wireless product to OPHC.
BOX, a business incubator in Harbour City.
CONTAINER, an incubator in the BOX.
DCMS, Department of Culture, Media, and Sports
DOCK, a creative digital centre in Harbour City.
Gold Autumn, a U.S company who provide RF Mesh network solution to OPHC.
Harbour City Council, a local city council of Harbour City.
Harbour City University, a university in Harbour City.
JEP, a multinational IT service provider.
NEXT Lab, a high-performance network Lab in Harbour City University lead by Susan.
Science Museum, a local science education centre in Harbour City
Straw House, a community engagement organisation in Harbour City.

Artefacts

Data Dome, the first application of OPHC & it aims to become an urban data visualisation device.
H-Net, a city-scale fibre network owned by Harbour City Council.

Cities

Harbour City, A middle-size city located in England (UK).
Plateau City, a city in England (UK)

Chapter 5

The Emergence of the OPHC

This chapter is the first empirical chapter of this thesis. It explores how the smart city project, Open Programmable Harbour City, came into being. The empirical data of this research relies on interviews, documents, and some participant observation to support this exploration. Section 5.1 talks about key episodes in the history of OPHC. The story is arranged in five sub-sections chronologically which are companied by a brief analysis. Section 5.2 draws on three key conceptual tools (*configuration*, *multi-level perspective*, and *prospective structure)* to analyse three key aspects that have contributed to the emergence of OPHC, including the unique local network of innovators; the dialectic interaction between actors and structure; and the retrospective and prospective function of vision. This chapter show readers a unique smart city birth story which is rare in any smart cities literature. OPHC was neither created in a vacuum, nor in a top-down manner. Instead, it is a *configuration* of people, artefacts, expectations that *survived* in the selection process at a *niche* level.

5.1 The story of the emergence of OPHC

5.1.1 The Digital Challenge (DC)

There are multiple entry points to tell a story of the emergence of OPHC which depends on when and where we press the start button. I would like to begin with an event called Digital Challenge (DC) because the event contributed to establishing both human and non-human pre-conditions for the emergence of OPHC. DC was one of eight digital strategies that were launched by the UK government in 2005. It aimed to act as a catalyst to develop e-enabled local public services and exploit the use of ICT according to the needs of local communities.

Initially, Harbour City Council did not want to join the competition, however, several local activists did perceive the opportunities of joining the competition. They went to Harbour City Council and suggested that "*Harbour City should become the best digital city in the UK*" (Interview with Ruby, 19 May 2016). Their proposal was accepted by the Council. This was followed up by a series of community meetings which attracted the participation of nearly 500 organisations (The official bid document; Interview with Richard, 17 June 2016; Interview with Camila, 28 June 2016).

Harbour City did not win the national DC award in the end, but this event contributed to the birth of OPHC in two ways. First, it contributed to the formation of a broad and deep innovator network in Harbour City. The network was broad because it involved a wide range of local stakeholders, such as, two local universities, Harbour City Council, a creative digital centre (DOCK), a community engagement organisation (Straw House), and hundreds of other organisations. The network was deep because it involved people who represented the organisations and could mobilise resources within their organisations (Schot and Geels, 2008). Moreover, what was significant about this innovator network was that there was a sense of collaboration between people. Before DC, apart from some small-scale collaborations, people had tended to work alone in Harbour City. DC provided local innovators with a chance to have a level of collective conversation about technologies and local opportunities. As one participant said, "*people used to work alone, but now they want to work together*" (Interview with Camila, 30 June 2016). Even after the DC competition had finished, the core nodes remained and connections between people had been established. When new funding opportunities emerged, they naturally re-connected and ran competitions together. We can read more about this in the next section and will see how they became key drivers for OPHC. Another thing DC contributed to OPHC was a fibre network. During the competition, Harbour City Council's digital asset fibre network H-Net was re-discovered. H-Net is a duct which was originally built for the radio service. Harbour City Council had purchased H-Net from a cable TV provider twelve-years before. Since then, Harbour City Council has refurbished and extended the network. The fibre optical cable was used to connect the council's own buildings and support council business (e.g. the CCTV network and traffic signals). The re-discovery of H-Net was important for OPHC because it was one of the key material enabler for the idea of OPHC. Without a fibre network owned by the local council, it would have been impossible to imagine a city-scale testbed OPHC.

5.1.2 Creating and modifying a configuration in response to a national digital infrastructure competition

(1) The initial configuration: Gigabit Harbour City

Another important event happened in the history of OPHC a few years later (2010). A national competition called Super Connected Cities (SCC) was launched by the Department of Culture, Media, and Sports (DCMS). The competition set a goal to create superfast connectivity across the UK by 2015. To support this goal, £100M was offered to support ten UK cities to increase their broadband speed up to 100 megabits per second. As Ruby, a civil servant, recalls, "*the minister has launched a project which is very ambitious. They said that we want all UK cities to have Singaporean level of connectivity. We are quite excited*." (Interview with Ruby, 19 May 2016)

The "we" in Ruby's interview refers to key innovators who came from different sectors in Harbour City, including Harbour City Council, the creative digital centre (DOCK), Harbour City University, and a community organisation (Straw House). They knew each other from the Digital Challenge competition. Although they had different motivations behind why they wanted to join the CC, one thing they had in common was that they found CC somewhat related to what they always do. For example, Brian, the director of the DOCK, noted the similarity between the CC and the high-speed broadband project that he was involved in 1999. At that time, he had worked with Vincent, a computer scientist from the local University, to experiment with high-speed broadband. So, he regarded CC as a "*natural next step*" for the experiment in 1999 (Interview with Brian, 15 June 2016). While Camila, a co-director of Straw House, regarded CC as an opportunity to tap the organisation's digital inclusion expertise. This is because Straw House had rich experience in the area of using media to engage local communities and she wanted to bring this agenda to CC. As she stated, "*we bring different voices (…). My challenge to the high-speed broadband is who will benefit from it? and how do people access it?*" (Interview with Camila, 28 June 2016).

In the end, innovators gathered at a weekend at the City Hall to draft the bid for the CC. They called this bid Gigabit Harbour City (Interview with Richard, 17 June 2016). The bid not only presented an alignment of the digital resources (e.g. H-Net) and human actors, but also incorporated an expectation of *providing people with free gigabit connectivity*. The assumption of this expectation was, "*providing people with free gigabit connectivity and they will come up with ideas about how to use it creatively*" (Interview with Ruby, 19 May 2016). There is a very interesting historical reference point for this assumption. It is the story of a Victorian engineer called Joseph Bazalgette. The interview with Ruby reveals how the connection between Gigabit Harbour City and the story of Bazalgette was made:

> **Ruby**: *There is an engineering story around it [Gigabit Harbour City]. When the Victorians developed London, there was a famous engineer called Bazalgette. He built a sewage and water system in London that was a hundred times bigger than London needed at that time, and because he built it so big, then you can have more and more people using the water and sewers. Our argument is that you need to do the same thing with digital.*
>
> **JW**: *More demand?*
>
> **Ruby**: *Capacity. You need to have more capacity than you know what to do with it. So, it creates an opportunity to grow new ideas (...).*
>
> *Interview with Ruby, 19 May 2016*

As we can see from the Ruby's explanation, the successful story of Bazalgette inspired the innovators in Harbour City to create the expectation for the Gigabit Harbour City project. They wanted to follow in the footsteps of Bazalgette and do the same with current digital infrastructure innovation. It seems that history will repeat itself in the form of digital infrastructure. It is worth pointing out that the retrospective tendency shown in this linkage neglected many conditions that enabled certain historical event. As Deuten and Rip (2000) argue, "*retrospective memories of the innovation process often forget many of the wide-ranging organisational and material contingencies upon which an artefact's future once depended*" (Brown and Michael, 2003: 9). Despite this, the retrospective tendency helped to make linkages between the current innovation and people's "ancestors". It also helped innovators to create alignment between the past, the current project, and the future. As Adam and Grove (2007: 112) argue, aligning an expectation with historical memories not only enables people to connect themselves with their ancestors and future generations of successors, but also to connect their actions in a seamless web.

The content of the bid reflected a *configuration* that was formed by local innovators. If we locate this *configuration* in a *multi-level perspective* framework, it is a *configuration* at a *niche* level. The meaning of this *configuration* which is very similar to STS's understanding of *heterogeneous engineering* (Law, 1987) is about the alignment of heterogeneous social-technical elements to achieve functionality. Those elements often include not only human actors with different interests, but also non-human actors, such as technological components and materials. As we can see from the Gigabit Harbour City bid, it contains the material element of the H-Net fibre duct and many local actors. However, the *configuration* shown in the Gigabit Harbour City bid suggests something that the conventional *configuration* concept does not pay attention to which is the element of expectation /vision. As shown above, the bid had an expectation to show people what the project was trying to achieve. This expectation has a specific function in this *configuration*. Drawing on the Sociology of Expectation's study of the function of expectation (Van Lente, 2012), I would like to argue that the expectation in the Gigabit Harbour City *configuration* functions as a *heuristic device* that guides people to build a high-speed digital infrastructure that anyone can access.

(2) The modified configuration: an experimental research testbed

The Gigabit Harbour City bid was successfully allocated £10M from the Department of Culture, Media, and Sports (DCMS) with the condition to provide a practical delivery plan, but, the original idea to provide everybody with gigabit connectivity ran into difficulties. This was because the prize money belongs to a category called State-aid. If local councils were to use this public money to provide free connectivity to everyone, private commercial network providers (e.g. BT and Virgin Media) would feel this undermined their business model. One real-life example is the case of Plateau City Council, which was brought to court by BT and Virgin Media because the free connectivity plan that they generated would bring unfair competition to commercial business (Interview with a local civil servant, 17 June 2016). So, in order to satisfy the industry, national government suggested ten DC cities use the funding to provide broadband vouchers for Small and Middle Size Enterprises (SMEs) to purchase fast connectivity. In the end, all other cities, nine in total, gave up the idea of providing free connectivity and adopted the strategy of providing vouchers for SMEs. Innovators at Gigabit Harbour City were unsatisfied with just providing vouchers, they still wanted to fulfil some of their original goals. In order to find a third way between their original plans and only providing SMEs with vouchers, the innovators embarked on a two-year long negotiation journey. People recall this was as a "*nightmare*" (Interview with Brian, 12 September 2016). As one witness Richard complained, "*six or seven versions of the delivery plans have been written, but they [DCMS] are still not satisfied…*" (Interview with

Richard, 17 June 2016).

During the negotiation period, a replacement expectation *experimental research test-bed* was circulated in the innovation network. Actually, this expectation was briefly mentioned in the Gigabit Harbour City bid and it was re-discovered when innovators needed to find a third way. Vincent, one of the early experimental research testbed advocates, explained that instead of simply providing additional broadband connectivity to conventional businesses, Harbour City could build a more experimental network to support the experimental usage of networking (Interview with Vincent, 7 June 2016). The expectation of building an experimental research testbed was approved by other local innovators because they saw similarities or connections between their past experience of experiment and the idea of experimental testbeds. For example, Vincent has rich experience in experimenting with technological designs and he knew the importance of using an experimental testbed to help a prototype project to scale-up. Camila regarded the experiment as a way to co-produce knowledge with citizens[8]. So, even though the word experiment means different things to different people, the word had the capacity to glue innovators together to agree to build an experimental testbed.

Adopting the idea of an *experimental research test-bed*, the revised bid proposed a new *configuration*. This *configuration* incorporated the technological element of the H-Net, human actors in the form of a group of local innovators, and an expectation of building an experimental research testbed. The modified bid was approved by DCMC. State-aid allowed the building of a high-speed network for research and experimentation purposes, because the word "research" sounds less contention to network providers. As Ruby explained, "*if people using the connectivity differ from their everyday business needs, the law of State-aid is allowed to fund a research project where would not allow to give everybody to get access to all their everyday activities*" (Interview with Ruby, 19 May 2016). The shift from the Gigabit Harbour City *configuration* to the experimental research testbed *configuration* suggests that innovators cannot create whatever *configuration* they want. The structure (*regime)* that the novelties (a niche level *configuration*) embedded in it might restrict their actions. Innovators have to anticipate selection results and make adjustments accordingly to it in order to *survive* in the existing restricted *selection environment*. I will come back to the restrictions of

[8] For more stories about people's past experience of "experiment", please see appendix 8 (1).

structure later.

5.1.3 Transforming an infrastructure innovation into a city innovation

(1) Adopting new actors and technologies

The modified bid approved by DCMC was not the end of the story. Actually, it was just the start of the trouble because the local innovators did not know how to deliver the idea. They explored many possible plans (see an example in appendix 8 (2)). Right at this time, Susan, a world leading optical network Professor, joined Harbour City University and heard about the project. She was excited by the idea of an experimental research testbed because before she came to Harbour City, she had already accumulated rich experience in the area of "landscape experiment of innovation", that is, creating an environment for people to experiment with new technological concepts. As she explained in the interview:

> *"I arrived at Harbour city with lots of experience. What we called the landscape experimental testbed for innovation. I have been involved in a number of international and national projects. What these projects have been doing were to create an environment that people can experiment with new concepts of technology. For example, one project called FIRE (Future Internet research and experimentation). The focuses of this project were to create an open environment and offer experimentation across Europe. Then, connecting those experimentations together and see how you are going to create the Internet of future (...)"*
>
> *Interview with Susan, 21 July 2016*

Susan thought that she could contribute her rich experiences to the experimental research testbed initiative. In return, the project would help further her knowledge in a real city context. So, she started to contact the innovators who were involved in the experimental research testbed project and to introduce the latest development in her field, Network virtualisation (NV). Network Virtualisation is a process of combining network resources and functionality as a single. It claims to bring revolutionary change to the current network industry. One thing it can do is to introduce the network programmability. What is network programmability? It is not the "programmability" that we are familiar with in the computing world where a programmer creates a set of instructions to tell computer what to do. Instead, it is a communication network terminology which is mainly used to describe the flexibility and configurability of a network. The idea of network programmability was not generated in a vacuum. It was inspired by the decoupling movement in the computing world. Many years ago, PC hardware manufacturers and software production started to decouple, and this separation lowered the barriers for people to enter the computing industry (Interview with Chris, 30 June 2016). Some people in the network sector think that the decoupling movement could also happen in the network industry. At the moment, communication network infrastructures are often tied to vendor specific equipment. So, vendors can sell their ready-made boxes to customers. In order to make current networks more flexible, the techniques of Software Defined Network (SDN) and Network Function Virtualisation (NFV) were introduced to the network. SDN means decoupling networking hardware from its control plane, and uses a centralized control plane to manage behavior of components in a network. Network Function Virtualisation (NFV) is a new way to design and manage service through decoupling the physical equipment from the functions (e.g. firewall or encryption) run on them. It allows network functions shared by multiple tenants and applications and to be programmed. In sum, the introduction of SDN and NFV have the potential to make a network more flexible, programmable, automated, elastic, open, and interoperable.

In considering how NV could contribute to building a city-scale experimental research testbed, Susan suggested that the NEXT Lab and Harbour City University's spin-off company Light Speed could utilise SDN and NFV to design two specific pieces of software for the project, namely, 'City OS' and 'Network Emulator'. 'City OS' is a piece of network software which functions as an operating system to orchestrate heterogeneous network resources in a city. The abbreviation 'OS' stands for operating system which can use the analogy of the 'OS' that we encounter everyday on our computers or phones. We might not see them with our naked eye, but they work behind the scenes to support the functionality of our computers and phones. Why do city networks need an 'OS'? The rationale is that nowadays, there are many different usages of the networks in a city (e.g. sensor network and fibre network) which are often separated. With 'OS', it is suggested, it is possible to link all the separate networks/network resources together and allow them to be reconfigured. Another piece of software called 'Network Emulator'. It is a technique to test the performance of real application over a virtual network. It can increase the experimental and scale-up capacity of a network. This is because a physical network in a city often has a certain number of physical 'nodes'[9]. When one computer connects to another computer, it is like one physical node talking to another physical node. In any network, at least three nodes are

[9] 'Node' a network communication terminology. It is a means physical point for network traffic conjunctions.

needed to create a network, because it can create multiple routes for information to be sent from one party to another. A 'Network Emulator' could replicate those nodes in a city and represent them in a virtual space. The virtual world can create a simulated environment with 100 or 1000 nodes. The simulated nodes could also be arranged into the network typologies that users want. So, this capacity would not only enable local people to test their products, but also allow people from other cities to use it: The 'Network Emulator' can create the virtual network environment of other cities and allow other cities to trial their technologies in the Harbour City's testbed. In other words, an experiment run in Harbour City can be scaled-up and applied to other network environments. I will come back to this piece of software in Chapter 7.

Not all the stakeholders of the experimental research testbed project fully understood the technical aspects of the SDN and NFV, but they saw the experiment composition those techniques might bring to the experimental digital infrastructure. For example, the 'City OS' could help to orchestrate the whole digital infrastructure and the 'Network Emulator' could help to scale up the infrastructure (Interview with Susan, 21 July 2016). So, Susan and a series of new technologies successfully become part of the project.

(2) The quantum leap

The introduction of new technologies brought new capabilities to the project and those new capabilities started to shape the simple idea of an experimental testbed. For example, one of main features those technologies added to the experimental testbed was network programmability. Based on this new feature, a series of ideas in relation to a city were developed, such as, the "programmable city" and "city experimentation as services". In the end, Susan found a name that better reflected the key features of those ideas and called it "Open Programmable Harbour City (OPHC)". The reason to call it "open" was because the testbed is free for anyone to use. The reason to name it "programmable" was because the testbed enables users to customize digital resources. The interview with Susan reveals the process of generating the name:

> *"I have a large group of researchers who are experienced in designing what we called 'infrastructure as a service environment'. So, that means we provide this infrastructure to people. They can do whatever they want. We took this concept and evolve to what we called 'city experimentation services'. Instead of 'infrastructure as services', we took the concepts of 'city experimentation*

as services' (...) We are offering this infrastructure for free to anybody, then we named our testbed 'open' (...). We see this as enabling actual users to be programming the infrastructure. So, we call it programmable".

Interview with Susan, 21 July

So, the expectation of *an experimental research testbed* gradually transformed into an expectation of *city experiment as a service*. A digital infrastructure innovation was transformed into a city innovation. Right at this time, the smart city became an emerging hot topic at a global level. Innovators of OPHC perceived the opportunity of making linkages between OPHC and the smart cities trend. It soon claimed itself as a smart city innovation.

The modified delivery plan-Open Programmable Harbour City, was re-submitted to the funder. The delivery plan illustrated a new *configuration* that consisted of the high-speed network H-Net, NV technologies, a network of innovators in Harbour City, an expectation of a *programmable experimental research testbed*, and it also relabelled itself as a smart city innovation. This *re-configuration* was approved by the DCMC with the condition that Harbour City Council had to form a joint venture with Harbour City University. This was mainly driven by the concern that Harbour City Council did not have the expertise to deliver it and it required expert input from Harbour City University. Both parties in Harbour City agreed to form a joint venture.

5.1.4 Enriching the configuration through alignments

(1) Alignments for the programmable testbed

In order to materialise the idea of OPHC, innovators then needed to expand the *configuration* through aligning more actors. On the one hand, they focused on aligning actors (both human and non-human) for the programmable infrastructure. For example, Susan took the lead in designing the testbed and making alliances for the programmable testbed. She started by designing the network infrastructure. As an optical fibre[10] network expert, she knew how to build a super-fast broadband network. The £5.3m funding from DCMS was used to upgrade the fibre to 144 cores[11] and to increase the capacity of the network. However, a city's network also consists of other networks (e.g. wireless communication) which were beyond

[10] Is a thin fibre glass with cladding layers that can carry light from one end to another end.
[11] This is a type of fibre that has 144 cores within a fibre tube. It allows a lot of light to come through it to convey large amounts of traffic.

her expertise, so she formed alliances with professors at the local University who had relevant knowledge. In the end, she designed the network infrastructure for OPHC which consisted of three networks: a fibre network, a wireless network, and a Radio Frequency Mesh (RF Mesh) network[12]. Unlike the fibre network which could utilise the existing fibre infrastructure in Harbour City, the wireless network and the RF Mesh network had to be built from scratch. After discussions, the OPHC committee decided to purchase an RF Mesh network solution from a U.S. company called Gold Autumn and bought some wireless components from a local company called Blue Arrow.

After sorting out the basic network infrastructure, Susan started to think about how to make all three networks programmable. Delivering the programmability of the network was not straightforward, because it was the first time that NV technology had been applied to a real city environment[13]. So, Susan and her engineering team had to design it from scratch. However, the funder (DCMS) set a deadline to use the funding. In order to meet this deadline, Susan and the OPHC committee decided to purchase the necessary components before designing the programmable testbed properly. As a result, they purchased a lot of equipment in advance to support the function of Network Visualisation, such as optical switch[14] and routers. Apart from buying equipment, Susan's engineering team started to develop an 'active node' and the 'City OS'. What is an 'active node'? 'Node' is a network communication terminology that describing the physical point for network traffic conjunctions. An 'active node' is a network node that can be programmed. Due to this flexible character, it is called an 'active node'. To provide you with an idea of an 'active node', I took a photo of an 'active node' and have highlighted its technical details in **Figure 19**. 'City OS', as discussed, is a piece of software which can be used to orchestrate all networks in a city.

[12] It is a communication network that made up radio nodes and those nodes can be organised as a mesh topology.

[13] The NV technique had been applied to a place like data centre, but it had never been used in a city-scale environment.

[14] A device that can selectively interconnect optical signals among different input/output to direct light to different destinations.

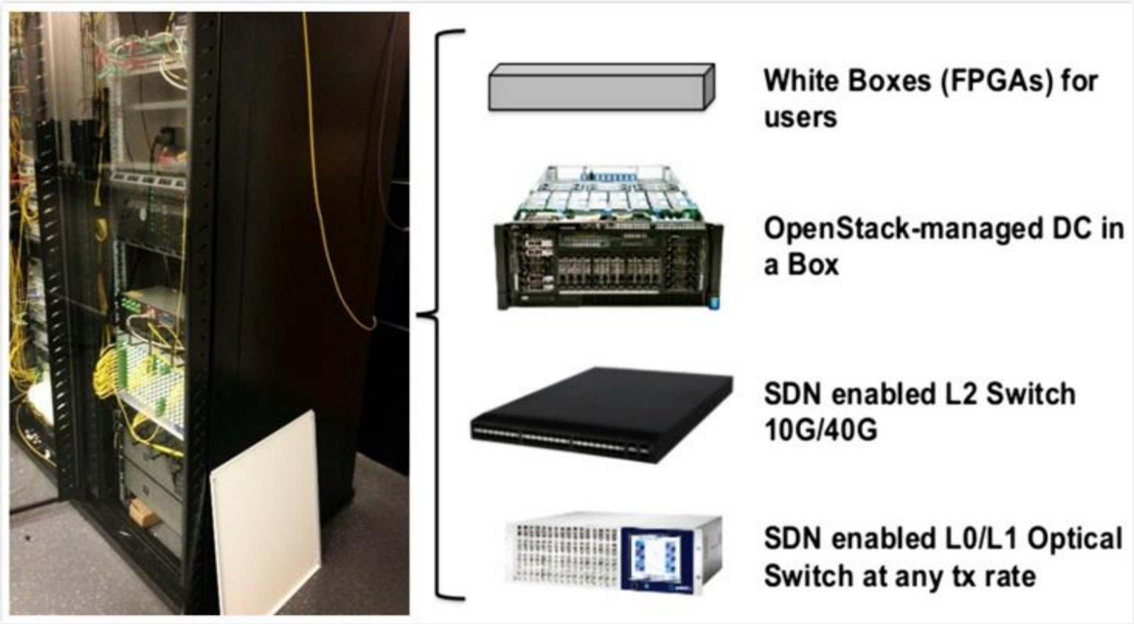


Figure 19. *An 'active node' in the NEXT Lab (left) and its technical components (right) (The technical details are extracted from OPHC's official presentation)*

(2) Aligning applications

The programmable testbed claims to enable many city related applications to run on top of it. However, nobody had actually thought about what these applications might be. Vincent, a computer scientist, was the first person to suggest a possible application for OPHC. This possible application was to create an urban data visualisation device called the Data Dome. The idea was also not born in a vacuum. A few years before, Vincent became a trustee of the local Science Museum and he soon noticed that the organisation wanted to upgrade its planetarium show system from a starboard projection system to a digital system. The digital system would to bring a more powerful visual experience to audiences. For example, it would allow a presenter to zoom in and out of the universe in an astronomy show, something that a starboard projection system cannot do (Interview with Vincent, 15 June 2016). Based on his knowledge in computing, Vincent further suggested that the dome could be linked to the local University's supercomputer. In this way, the dome could be transformed into a powerful visualisation screen backed by powerful computing capability. In his words "*the dome is a like a big PC screen*" (Interview with Vincent, 15 June 2016).

However, this idea of connecting the dome to a supercomputer did not materialise until the opportunity of OPHC emerged. As member of the local innovation network, Vincent witnessed the negotiation process between OPHC and DCMS. He noted that the dome could be an application for OPHC. In order to make the funder feel comfortable to spend money on scientific visualisation, he then came up with the idea to upgrade the dome and make it the first application for OPHC. He suggested to link the dome to OPHC and the supercomputer[15] in Harbour City University. This design would transform the dome into an urban data visualisation device and a space to visualise urban data (e.g. environmental data and traffic data) (I will expand more on this expectation in Chapter 6). The OPHC committee accepted Vincent's proposal and called the idea ‘Data Dome’. The idea was also added as an appendix in the final version of the OPHC delivery plan. In the end, before Christmas 2014, DCMS specifically added an additional £1M to OPHC to build Data Dome.

(3) Aligning local host partners

Alongside building alignments for infrastructure and application, Luke (the Manager of OPHC) and his successor Chris (the Chief Manager of OPHC) started to create alliances with local institutions and organisations. Local organisations who were willing to become local host partner of OPHC were called host partners; this was because they could help host ‘active nodes’ as well as use the OPHC testbed. Several factors influenced the selection of host partners. First, they should have some digital resources that could link to OPHC. Second, they should have some the human resources that could use OPHC.

However, the alignment of host partners was not straightforward. Sometimes it was simply because organisations did not want to participate. For example, a local Japanese technology research lab was an initial partner of OPHC, but did not sign up in the end because the company was more interested in building applications rather than developing a platform (Interview with Brown, 11 May 2016). Other times, it was due to the restrictions of State-aid. For example, innovators had wanted to put an ‘active node’ in a famous local animation company. However, they had to give that up because the funding was State-aid. The funder worried that private companies might utilise the infrastructure for commercial purposes.

Despite many difficulties, innovators successfully aligned four organisations/institutions in Harbour City who were willing to become host partners of OPHC. We are already familiar with their names from the story above. The first organisation is Harbour City University. It would contribute its supercomputer facilities as well as rich know-how skills to the project,

[15] It is a computer with high level performance than general computers.

especially in the areas of high-performance networks, wireless communication, supercomputer, and media visualisation. Susan's NEXT Lab naturally became a space to host one of the 'active nodes' because it was close to many networks know-how resources. The second organisation was the Science Museum, a local science education centre. It would bring "eyes" (data visualisation capability) to the OPHC network. The third organisation was a local digital creative centre, DOCK. The organisation has a cluster of creative digital workers with a reputation for producing creative and fun projects. The creative class in the DOCK was supposed to come up with more use cases for OPHC. The fourth organisation was BOX which has many IT focused businesses in it, especially the incubator CONTAINER that has a high hatch rate across Europe. In theory, connecting BOX would encourage local SMEs to use OPHC. Apart from those four nodes, other local organisations also wanted to be a host partner. Straw House, for example, eventually become the fifth local host partner as we will see in Chapter 6.

(4) Aligning big corporations

Luke and Chris also sought to align big businesses. The alignment of big corporations contributed to OPHC in two ways. First, the involvement of big businesses would make the project look more credible. Second, big companies could help SMEs to move into the market. The idea was that developers who experimented with their products through the programmable infrastructure could either establish their own companies or sell their products to big businesses. The involvement of big business was for the latter purpose. So, Luke invested a great amount of time to convince big businesses to partner with OPHC. However, he left the project in 2014 and this job was handed-over to his successor Chris. In the end, Chris successfully enrolled OPHC's first business partner, a multi-national IT service and product provider calls JEP. JEP was interested in OPHC because the company is an SDN solution provider. OPHC needed JEP's SDN solutions. In return, it would test its SDN solution through OPHC. Moreover, it perceived possible positive linkages between OPHC and Harbour City Council. It wanted to sell its products back to Harbour City Council as well (see more in Chapter 6).

The ongoing alignment of actors around OPHC provided more substance for the idea. For example, the alignment of the technological components and the suppliers provided more detail to the idea of the programmable infrastructure. The alignment of the application, Data

Dome and some partners (local host partners and business partners) around the project helped define how the infrastructure could be used and who going to use it. For clarity, I have listed key technological components, partners, and mutual interests between partners and OPHC in **Table 1** below. The alignment process enriched the initial *configuration* of OPHC and this enriched *configuration* provided the foundation for Chris to produce the vision of OPHC. I will elaborate this later.

Table 1. *The main alignments formed around the OPHC*

Main Human and non-human actors aligned around OPHC			
Technological components	**Partners**	**Partners' interests**	**OPHC' interests**
144 core fibres	Gold Autumn	Selling products to OPHC.	Purchasing RF Mesh network solution.
RF Mesh network	Blue Arrow	Selling products to OPHC.	Purchasing wireless products.
60GHz Lightning modules	University of Harbour City	Increasing the University's reputation and have an opportunity to research in the wild.	Gaining more research projects to use the testbed and hosting the active node.
Optical switch	Science Museum	Upgrading its Dome infrastructure.	Having the first application and hosting the active node.
City OS	DOCK	Utilising the infrastructures for the next generation experiment.	Finding use cases (e.g. 'Fun City') and hosting the active node.
Supercomputer	BOX	Testing their products.	Finding use cases and hosting the active node.
Dome	JEP	Testing SDN solutions in a real-life city environment.	Providing SDN components and use cases.

5.1.5 Creating a vision statement for OPHC

At this stage of the development, Chris replaced Luke and became the Chief Manager of OPHC. With a business to business marketing background, Chris very quickly realised that OPHC at that time did not have a clear message to communicate to the world (Interview with Chris, 30 June 2016). In order to better communicate OPHC to the general public, he thought, there needed to be a simple story. The quotation at the beginning of this chapter reflects this concern. So, Chris spent six weeks creating a vision statement for OPHC. The vision statement arranged facts and future possibilities around the idea of OPHC. It tidied up the messy emerging history of OPHC as well as illustrating a promising future. It mainly contained three aspects: the rationale for the project, the vision itself, and the business model.

(1) Linking OPHC to Promising Trends

Coming from a marketing background, Chris knew the importance of answering the question "why" in communications. As he states, "*in marketing theory or marketing practices, you need to actually answer the question why very fast. If you cannot explain why, why are we doing this? People do not know why they are listening (…)*" (Interview with Chris, June 30, 2016). Based on characteristics of OPHC, Chris creatively aligned OPHC with three promising trends to address the question "why", namely, the trend of smart cities, two specific technological trends, and the future city making trend in Harbour City.

The first trend he related to OPHC was the trend of smart cities which comes from a background of the rapid urbanisation globally, which causes many problems for already suffering cities such as congestion, ageing populations, waste, etc. All those problems are being faced with less government money and technologically smart cities are regarded as a solution. OPHC followed the trend of smart cities by proposing an experimental testbed to test smart city solutions. Although OPHC had successfully transformed from an infrastructure innovation to an urban innovation, it had never claimed itself so explicitly as a smart city innovation. In the vision statement, Chris explicitly talked of OPHC as a smart city project which responded to *landscape pressures* (e.g. urbanisation and demographic shifts).

The second type of trend he associated with OPHC were technological trends. Chris mentioned two specific technological trends. One was the trend of the increasing consumption of technologies and the production of data. This trend suggested that connectivity is essential for the future. As Chris stated, "*machines will gradually use more bandwidth than humans*" (Chris's presentation at a local digital health event, May 2015). OPHC is a response to this trend because it would provide people with up to 30Gbps connectivity which would be 30 times faster than the world fastest connectivity. The other trend was the Network Visualisation (NV). I explained the revolutionary possibilities this trend might bring to the network industry earlier (section 5.1.3). OPHC following this trend by claiming to be the first SDN city in the world.

The third type of trend was popular future city ideas in Harbour City. Harbour City had recently made a strong commitment to making a ‘future city’. So, many future cities initiatives had popped-up in the city, such as ‘green city’, ‘resilient city’, ‘fun city’, and the ‘citizen central’. OPHC suggested that the OPHC testbed could help further develop those already existing local future city initiatives. To associate OPHC with those local future city trends could help OPHC better articulate its vision at a local level.

(2) The content of the vision

After providing rationales for why to develop OPHC, Chris further illustrated what OPHC is about, the vision of OPHC. For clarity, I have provided a figure of the content of OPHC in **Figure 20**. As we can see from the figure, project OPHC mainly consisted of two parts: the programmable testbed of OPHC and an ecosystem of users around it. Because both aspects were merely expectation, I would like to call the vision of OPHC a *prospective structure* (Van Lente and Rip, 1998). Above, I have introduced the idea that a *prospective structure* is a ‘not-yet structure’ which made up links in texts. Although the structure is not yet realised, it might orientate people to take actions to realise it. I will come back to this later (section 5.2.2).

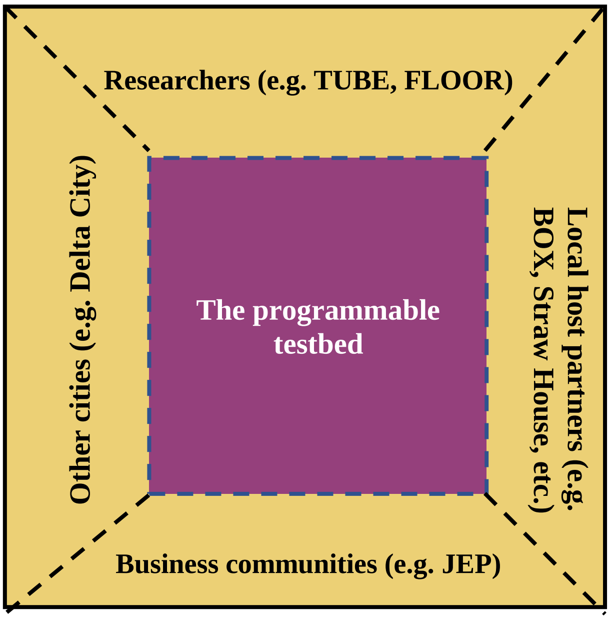


Figure 20. *The content of vision of OPHC*

The programmable testbed is the foundation of the project. Chris summarised key technological components of the programmable infrastructure and asked a visual designer to represent them in a tube-like map. This map was printed on all OPHC related materials. For anonymity, I made a simplified map with the key messages in **Figure 21**.

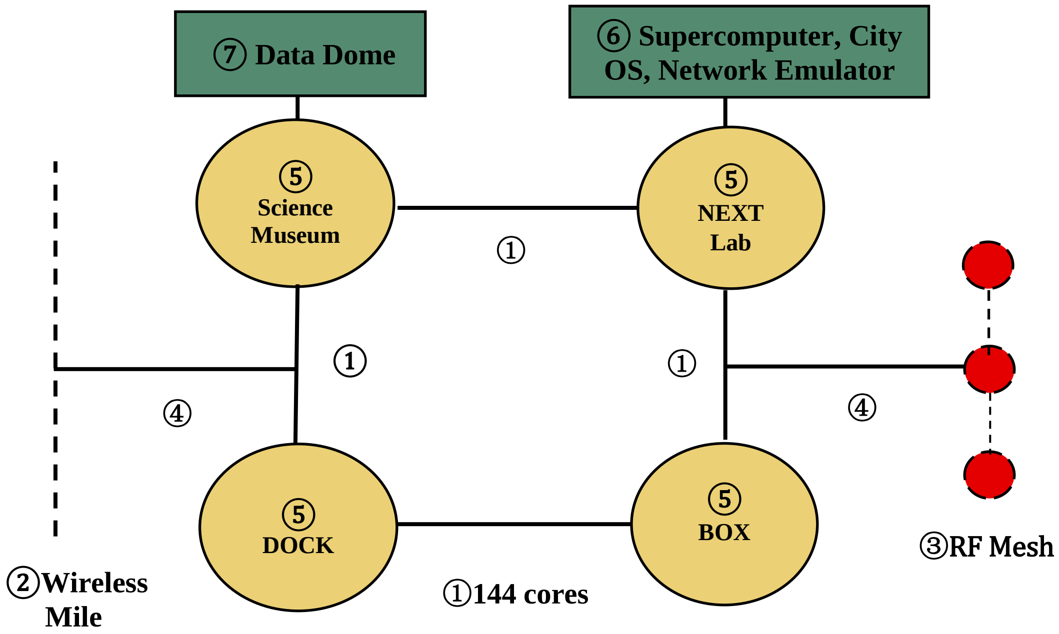


Figure 21. *The layout of the programmable testbed*

As we can see from the **Figure 21**, the OPHC infrastructure consists of three networks: the 144 cores fibre network (see ①), a mile of heterogeneous[16] wireless network (Wireless Mile) (see ②), and an RF Mesh network to be deployed on 1500 lampposts across the city (see ③). Both the Wireless Mile and RF Mesh network were to be connected to the core fibre network (see ④) which allow data collected from both wireless networks to send to the fibre network. The fibre network connects the host partners by four 'active nodes' which are placed at four locations (NEXT Lab, Science Museum, DOCK and BOX) (see ⑤). The 'active node' in the NEXT Lab further connects to the supercomputer facility in Harbour City University and associated with two software ('City OS' and 'Network Emulator') (see⑥). The 'active node' in the Science Museum linked the dome to OPHC (see ⑦). It is worth mentioning that not all features described in the figure have been realised. For those 'not-yet' realised features, the vision statement provides a timeline, such as, Data Dome

[16] The reason to say it is heterogeneous because it includes components such as Wi-Fi, 3G, 4G, millimeter wave, and a section of 5G technology test-bed.

opens in November 2015, IoT Mesh[17] to be ready to use in April 2016, 5G[18] and SDN controller to be available in summer 2016. There is more on actual materialisation process of those features in Chapter 6.

Regarding the programmable testbed, the vision statement also made linkages between the programmable testbed and an ecosystem of possible user groups. As we see from **Figure 20**, there is a ring of ecosystem actors outside the square. The vision statement specifically highlighted four groups of users that can use OPHC. The first group is academic researchers. Scholars in two local universities were used as an example to support this claim because they had the technological know-how skills (e.g. data science, computing, networking and network security, etc.) to use the OPHC infrastructure to research in the wild. For example, it was suggested that two existing research projects (TUBE[19] and FLOOR[20]) at the Harbour City university could use the testbed. The second group was the local host partners. For example, creative designers and projects in DOCK could use OPHC infrastructure to further their research. SMEs in the BOX could test their solutions before putting them on the market. Moreover, Straw House, a local media community organisation added to this group. It could help OPHC to engage citizens all the ways through the project. The third group was business communities, ranging from large companies to the start-ups. JEP is an example of a large company. Blue Arrow who sells its equipment to OPHC was mentioned as an example of an SME and start-ups user who can use the testbed. As one spokesman of OPHC said, "*Harbour City has the largest digital cluster outside London, and it has the highest workforce in any English core city region. The infrastructure of OPHC enables a variety of technological businesses to trial their solutions, ranging from technology readiness level one (technology which is close to the market) to technological readiness level nine (technology that is far from the market)*" (Presented in the local digital health event, May 2016). The last category is other cities around the world. As Chris expressed explicitly "*the buyers of OPHC are cities*" (Interview Chris, 30 June 2016). Similar to other smart cities projects around the

[17] This another name for RF Mesh network.

[18] It is the 5th generation wireless system. It provides faster and better Internet access than the 4G that we use nowadays and with enhanced telecommunication standards.

[19] TUBE is a research project from the NEXT lab. It explores the method of synchronising the heterogeneous networks. The project TUBE could use OPHC infrastructure to further its knowledge of network convergence.

[20] FLOOR studied sensor platforms in residential environments. The connection between a sensor house and OPHC is a scenario that the high-speed broadband of OPHC could help forward large files generated from the house (e.g. video).

world which have ambitions to become a model for other cities, OPHC also wants to scale-up and mobilise its vision to other cities. This could be realised either through selling the SDN network solution to other cities or by letting other cities try their solutions through the OPHC infrastructure (Harbour City News, 11 March 2015).

(3) An initial business model of OPHC

A business model was also presented at the end of the vision statement. Although OPHC is funded by DCMS, it required additional money to cover operation costs and staff salaries. In order to get the money to run the project, a business model was required. The key elements of the business model are summarised in **Table 2**. As we can see from the table, users of OPHC are regarded as partners and are divided into three categories: long-term partners, project partners, and eco-system partners. The long-term partners include people and organisations who use the network to do research (e.g. researchers); use the network service; and experiment with network infrastructure (e.g. JEP). They pay a fixed fee to the OPHC. In return, OPHC allows them to access the network to conduct experiments and provide engineering support. The project partners are partners who collaborate with OPHC on specific projects. They pay a project specific fee to OPHC. The ecosystem partners refer to SMEs, community organisations, local governments, and foundations. Examples of this type of actors are people from Straw House, DOCK, and BOX, etc. They collaborate with OPHC to form a lively ecosystem around OPHC. So, in order to encourage them to use the network and balance the cash flow, Chris decided that ecosystem users could use a pay-as-you-go method to use the network and there is a special small payment system designed for them (Interview with Chris, 30 June 2016).

Table 2. *The business model of OPHC*

The initial business model of OPHC		
Partner type	**Examples**	**Fees**
Long-term Partners	Research experiment, network services, and experiment of the evolution of network and infrastructure.	Fixed membership fees
Project partners	Bespoke activities	Project fees
Eco-system partners	SMEs, Community organisations, institutions, local government, and foundations.	Pay-as-you go

5.2 Understanding the Emergence of OPHC

From the descriptions and brief analysis above, we can see that the emergence of OPHC does not fit into the conventional imaginations about the birth of a smart city. In those popular imagining, a smart city is often led by visionaries (e.g. big corporations and actors in authority) and created in a vacuum. However, the birth of OPHC presents a rather different picture. Many factors contributed to the birth of OPHC, including a network of local innovators, the structures that the novelties were embedded in, the alignment processes, and the formation of the vision. Above, I conducted some brief analysis within the context. Below, I would like to draw on some conceptual tools (*configuration*, *multi-level perspective*, and *prospective structure*) to further some of those discussions.

5.2.1 A local network of innovators and evolving local configurations

The key drivers behind OPHC are a network of local innovators, who come from different areas in Harbour City, including the local Council, the local University, a community organisation, a digital creative centre, etc. This network of innovators was formed gradually in Harbour City, mainly stimulated by big events, such as the Digital Challenge (DC). To some degree, we could say this network was open to cooperation. For example, many of them were willing to run projects together and they were open to adopting new actors, such as, the involvement of Susan at the late stage. However, the network was not completely open. People would be part of the network either if they were interested in digital innovation or if they could bring something to the network. Whereas, ordinary citizens without skills and interests in technology were less likely to become part of this innovator network.

To have a network of innovators in Harbour City was important for the emergence of OPHC, because they were sensitive to innovation opportunities at both national and international levels. Without this network of innovators, OPHC might not even exist, or it would have become a different project. As we see above, this network functioned as a mediator, constantly mediating external innovation opportunities and local resources. For example, when the innovation opportunity, Super Connected City (SCC) programme, was announced, this network of innovators creatively made linkages between heterogeneous local digital resources (e.g. fibre network, dome and supercomputer) and actors (e.g. human and institutions). From a socio-technical perspective, the alignments of those human and non-human actors could be regarded as *configurations*. However, as I argue above the *configuration* in the case of OPHC was not merely a socio-technical *configuration* because these *configurations* also have an element of expectation/vision in them. This might be especially the case for an early stage innovation where nothing is solid. Expectation/ vision has a role to play in a novel *configuration*. For example, there are three *configurations* that can be identified in the story: The Gigabit Harbour City, the experimental research testbed, and the Open Programmable Harbour City (OPHC). Each *configuration* has an expectation, such as *providing gigabit connectivity to people*, *building the experimental research test-bed*, and *making programmable infrastructure*. Drawing on the Sociology of Expectation's study about expectation (Van Lenten, 2012), I would like to argue these expectations were incorporated in the *configurations* function as *heuristic devices* which suggested the future innovation directions.

5.2.2 Structures restrict innovation as well as provide opportunities for innovation

Innovators in Harbour City have not always been able to create the *configuration* according to their desires. From the series of *configuration* and *re-configuration* activities above, we can see that the novelty is not born in a vacuum. It is embedded in an existing structure, and this structure can restrict as well as enable innovation. Multi-level perspective (MLP) provides us with a framework to understand the interaction between novelties and their structures. MLP creates three analytic levels: *niche* level, *regime* level, and *landscape* level. Novelties often exist at *niche* level where they are provided with protections. In the case of OPHC, a series of three *configurations* mentioned in the story could be regard as novelties at the *niche* level. Novelties cannot freely diffuse and grow, because there is a *regime* structure above them. *Regime* is the existing stabilised social-technical system in the area of technology, science, politics, market, user preference, and cultural meaning. *Regime* can create barriers for novelties and stop them growing freely. The restrictions often come from existing *rules* at the *regime* level. MLP summarises three types of rules: *cognitive rules* (e.g. belief, search agenda, heuristic), *regulative rules* (e.g. law and regulation), and *normative rules* (e.g. value and norms). In order to *survive,* innovators at *niche* levels have to anticipate selection results from the existing environment (*regime*) and re-configure the novelty accordingly. This is influenced by the quasi-evolutionary theory that regards a novel innovation as a *variation* that receives protection from a *niche* and seeks to *survive* the *selecting environments*. One key point of quasi-evolutionary theory is that *variation* is not generated isolated from the *selection environment*. Instead, *variation* and *selection* are interrelated. One way they are linked is through innovators (human actors)'s anticipation activities. Innovators can anticipate and strategically interpret the selection results from the environment and constantly make relevant adjustments in order to *survive* in the existing environment (Schot and Geels, 2007; Grin et al., 2010). Above the *regime* level, there is the *landscape* level. This refers to the long term exogenous trend that influences the *regime* and *niche* levels. Change at *landscape* level might not directly affect innovation at *niche* level, but it can create pressure on the existing *regime* level. This might open *windows of opportunity* for novelties at a *niche* level to emerge and replace existing structures at a *regime* level.

In the case of OPHC, the structure at the *regime* level and the *landscape* level created frustrations as well as providing opportunities for local *niche* innovations. We can find examples from above. The first example is how the structure restricted innovation: In the episode of forming the Gigabit Harbour City *configuration*, an idea to provide people free with gigabit connection was suggested. However, this idea faced challenges from the existing *regime*. Resistances came from the normative *rule* and *regulative rules* at the *regime* level. The *normative rule* was the existing way of doings things and values in the network industry. In the current UK context, broadband services are provided by private network vendors, such as BT and Virgin Media. They explicitly protested the expectation of *providing people free gigabit connectivity* because they claimed it would affect their business model. The *regulative rule* refers to competition law in the UK. According to competition law, public money (State-aids) cannot be used to support a project that creates unfair competition for private companies. Both *rules* at *regime* level made innovators at the *niche* level modify their original plans in order to *survive*. They anticipated the likely selection results from the *regime* level and adjusted the local *configuration* by adopting the idea of an experimental research testbed. The structure also created opportunities for novelties at the *niche* level to grow. An example can be found in how OPHC was linked to the global trend of smart cities. As we see above, alongside innovators in Harbour City who were busy finding a delivery plan for the infrastructure innovation, change at *landscape* level (e.g. demographic shift and aging population) created pressures on the current *regime*. This pressure required the existing *regime* to change its structure. It provided a *window of opportunity* for the emergence of the 'smart cities'. The idea of technological smart cities was proposed under this pressure. The social-technical future that was incorporated into the idea of smart cities could help to release these pressures. Local innovators in Harbour City perceived this opportunity to link OPHC with the trend of smart cities. They creatively relabelled the existing infrastructure innovation as smart city innovation. They claimed OPHC not only shaped the existing *regime* of how the city was run, but also might bring revolutionary change for how the communication network industry is run at a *regime* level.

5.2.3 Creating alignments and a vision for OPHC

After a series of interactions between local innovators and the selection environment, OPHC is the *configuration* that *survived* from the selection environment. In order to enrich and nurture the idea of OPHC, innovators in Harbour City went through a process of forming alignments around the idea. They started by developing a clearer picture of the programmable testbed. This was followed by a series of alignment activities in relation to the programmable infrastructure, including people with professional know-how skills (e.g. wireless communications professors); technological components and suppliers (e.g. optical switch, Gold Autumn, Blue Arrow). Then, they also found a wide range of possible use cases and users for the programmable infrastructure, such as, an urban data visualisation device (Data Dome), several local host partners, and a big partner corporation.

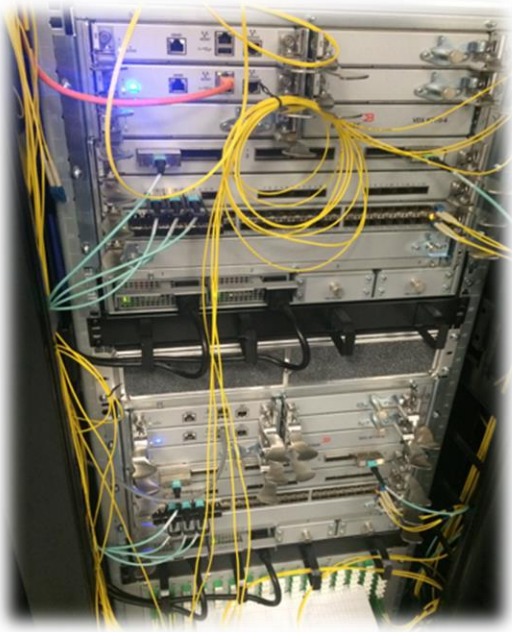
Despite actors having different reasons for enrolling in OPHC, they brought more substances to the project. This was reflected in the vision statement that was created at a later stage of the birth process. The vision statement introduced the programmable testbed of OPHC and the ecosystem of users around it. It also gave a rationale for the project and suggested a business model. The beautiful story of a smart city illustrated in the vision statement of OPHC is partly fact and partly fiction. For example, some elements in the vision had already been realised at the time of drafting the vision, such as upgrading the fibre to 144 cores and installing ‘active nodes’, etc. While, some elements were waiting to be done, such as, upgrading the dome, connecting different parts of the infrastructure together, opening the RF Mesh network. However, there are some elements in the vision statement which were just potentials. For example, the four types of ecosystem actors with possible examples mentioned in the vision statement were merely potentials, not reality.

I would like to argue that the vision statement of OPHC was not merely descriptive. It contributed to the birth of OPHC in two ways: the retrospective function and the prospective function. Like Janus's Head, the two-headed God looks to the past as well as the future. When the vision looks backwards (retrospective function), it tidies up the messy birth process of OPHC and pulls together multiple social interests, expectations, and networks of actors (both human and non-human actors). This function is similar to what Latour (1980) calls 'fiction-building'. Latour observed that in a Lab study, scientists have the capacity to structure the world afterwards (Van Lente, 1993: 72). What the innovators of OPHC did here is similar to scientists in the lab, because they gave order to the chaotic process of the emergence of OPHC after the event. When the vision looks forward, it illustrates a 'not-yet structure' which allocates roles to many actors and artefacts. This 'not-yet structure' is what Van Lente and Rip (1998) calls a *prospective structure*. It is a structure which *scripts* heterogeneous actors (human and non-human); makes linkages between different actors in a text; allocates a role for itself and others. The reason it is called *prospective* is because not all the elements mentioned in the structure are realised at the moment of forming the vision. This future oriented 'not-yet structure' "does" something. It invites people and organisations who have been *scripted* in the vision statement to take up the roles allocated to them. For example, in order to realise the vision of OPHC, the non-human actors such as the technological components should work together to deliver the programmable infrastructure and some prescript application (e.g. Data Dome). Human actors, such as individuals and organisations, need to take the role assigned to them and act towards realising those roles. We will see more about how these *scripted* actors interact with the *prospective structure.*

5.3 Conclusion

The story-telling and analysis in this chapters shows that the birth of OPHC was very messy, speculative, and complex. It contradicts the conventional stories of emerging smart cities that we often read in the literatures, where smart city projects are either created by big-corporations or actors in authority using a top-down model. OPHC went through a very unique birth journey. It is a *configuration* of people, artefacts, expectations that survived in the selection environment at a local *niche* level. This *configuration* was originally created by a network of local actors in response to a national digital infrastructure competition. The network of local actors had certain degree of agency to create *configurations* and link opportunities (e.g. 'smart cities'). However, their action is also restrained by the structure (*regime*). For example, the original Gigabit Harbour City *configuration* was restricted by the regulations and mind-sets of the current telecom industry at the *regime* level. In order to *survive* in the existing environment, innovators had to anticipate the selection results from the environment and modify the *configurations* accordingly.

A *configuration* emerged as a result of this interaction and it provided material, social, technological, and expectation foundations to OPHC. This *configuration* was later creatively bridged to the trend of 'smart cities'. A vision of OPHC was created in the end to tidy up the messy birth process and relabelled the *configuration* as a smart city project. This vision statement is a *prospective structure* which sought to mobilise the future to the present. In the next two chapters, we will explore to what extent the vision of OPHC was enacted in reality. Chapter 6 studied how this vision was implemented in Harbour City. Chapter 7 explores how the vision of OPHC was diffused beyond Harbour City to the world.



"Whenever something is useful and available, it has to be integrated as part of the platform."

Interview with the head of OPHC engineering team, 10 September 2016

"The Data Dome is an opportunity to build not because there are real-time data coming through the OPHC network and waiting to project onto the Dome. The infrastructure is not set-up to do so (...)"

Interview with a member of Data Dome team, 05 October 2016

"They talk as if the infrastructure (OPHC) is there and waiting for people to use."

Interview with a member of Citizen Sensing team, 30 June 2016

Cast II

Site 1: Programmable infrastructure

Charlie, a researcher in the NEXT Lab.
Carlo, a researcher in the NEXT Lab.
Chris, Chief Manager of OPHC.
David, the head of OPHC engineering team.
EXTRA, a mobile technology company.
Harbour City University, a local university in Harbour City.
Hazel, a researcher recruited by OPHC to facilitate research around OPHC.
JEP, a multinational IT service provider.
NORMAN, a communication device and service provider.
NEXT Lab, a Lab in Harbour City University led by Susan.
OPHC engineering team, is the engineering team of OPHC. It includes **David** (the head of OPHC engineering team) and another 2-4 engineers.
OPHC business team, is a small team in charge of promoting OPHC and aligning partners. It includes **Chris** and **Rufus**.
Ruby, a civil servant from Harbour City Council.
Rufus, a member of OPHC business team.
Sam, a member of staff from the BOX
Susan, the Chief Technology Designer of OPHC.

Site 2: Data Dome

Chris, the Chief Manager of OPHC.
Data Dome team, a team of actors lead the Data Dome innovation including **Peggy**, **Jim**, **Henry**.
DOCK, a creative digital centre in Harbour City.
Digital Moon, a digital planetarium solution provider.
Future City Radar (FCR), a UK government support agent.
Henry, a member of Data Dome team.
H&C, a British multinational company.
I-LOOK, a digital content design company.
MiniCat: a U.S multinational technology company.
Orbit Game, a Virtual Reality company in Harbour City.
Peggy, a member of Data Dome team
Jim, a member of Data Dome team
DOCK, is a local digital centre.
Science Museum, a science education centre in Harbour City.
Tim, a game developer at Orbit Game.
UK BROADCAST, a British national wide media company
WISO, a server provider for Data Dome.

Site 3: Citizen sensing

Citizen Sensing team, a group of actors (**Camila**, **Stein**, **Judy**, **Lucy**, **Maria**) lead the Citizen Sensing innovation.
Camila, a co-director of Straw House.
Gold Autumn, a U.S company who provide RF Mesh solution to OPHC.
John, a data analyst from Harbour City & the initial designer of the Toad.
Judy, a staff of Straw House.
Lucy, a staff of Straw House.
Maria, a PhD researcher.
Michael, an actor from a local energy company.
Straw House, a community engagement organisation in Harbour City.
Stein, a co-director of Straw House.
Zack, a developer in Harbour City.

Chapter 6

The implementation process of OPHC

By the end of the last chapter, we could see that a beautiful vision of OPHC had been produced. Following up, this chapter looks at how the vision of OPHC was rolled-out in Harbour City. The data in this chapter is based on my 17 months of participant observations and interviews. The implementation process was carried out in three parallel sites: the programmable infrastructure site, the Data Dome site, and the Citizen Sensing site. The process of sampling those sites has already been discussed in Chapter 3. They are pulled together in this Chapter because they are the main activities that I observed in relation to the implementation of OPHC. I introduce them accordingly in three sections. Section 6.1 explores the innovation activities around the programmable infrastructure. Section 6.2 looks at the innovation process of OPHC's first application Data Dome. Section 6.3 studies the process whereby Straw House co-produced a Citizen Sensing application (Toad) with the local community for OPHC.

Within each section, I draw on conceptual tools from Strategic Niche Management (SNM) and the Sociology of Expectation (SOE) to conducted site specific analysis. The conceptual tools include niche internal mechanisms (*articulating expectation*, *building social network*, and *learning*), performative role of expectation (*promise and requirement cycle*, *forces of expectation*). Section 6.4 deepens the analysis by looking across the three sites and summarises the key implementation mechanisms. The analysis suggests the implementation of OPHC was loosely coordinated by a network and a vision, which occurred in three niche experimentations. It highlights two issues in the implementation process: the lack of coordination between sites and the challenge of citizen engagement. In the end, it also explores why failures in each site did not lead to the failure of the overall OPHC project.

6.1 Making the Open Programmable Infrastructure

6.1.1 Delivering the Programmable Testbed

Five months after the official launch date of OPHC, David arrived in Harbour City in August 2015 as the head of the OPHC engineering team. He was excited about this new job because from his previous work experience in the telecom industry, he saw the revolutionary potential that Network Virtualisation (NV) might bring to the current network industry. Given OPHC's claims to become the first SDN city in the world, David felt that working with OPHC would associate him with this future trend. His job was to lead the OPHC engineering team to deliver the programmable testbed.

He has a desk in the NEXT Lab, a place in the Harbour City University that hosts one of OPHC's 'active nodes'. In the first few weeks, David had no clue about what to do. In front of him were a tube-like map (see **Figure 21**), two engineers in the OPHC engineering team, and many disconnected infrastructure components (optical switches, routers, LTE-A[21], Etc.). It is not difficult to understand David's situation. From Chapter 5 we know that Susan and other managerial level people in OPHC felt obliged to purchase equipment before designing it properly in order to meet the funding deadline. So, the work of delivering a programmable testbed included connecting those already purchased components and designing other missing details of the testbed. It was an adventure for David and the OPHC engineering team because they were going to build the first city-scale SDN testbed with has no pre-existing model to copy from.

(1) Setting up the physical infrastructure

David decided the first thing to do was to connect the physical components of the testbed. They called this job as "*network set-up*". The "*network set-up*" is a bit like setting-up a domestic Wi-Fi network, but more sophisticated and complicated. This was not merely an issue of scale and the number of components involved, there was also the issue of re-engineering. Because not all purchased off-the-shelf equipment supports the idea of programmable networks, in order to make purchased components fit into the vision of a programmable infrastructure, the OPHC engineering team had to re-configure some of the

[21] LET-A indicates Long Term Evolution-Advance. It is a mobile communication standard of 4G.

equipment and make them support the idea of network programmability. Ruby recalls the difficulties of configuring technological components:

> *"It was supposed to be a three-year project and we had to deliver it in about six months. We were buying equipment which was absolutely the state-of-art (...). Some of the equipment we bought, Susan had to test each item to make sure that it worked. Actually, to get things working together is difficult. We still had some problems, because we did not necessarily buy the right things. We did not necessarily get them working together properly (...)"*
>
> *Interview with Ruby, 19 May 2016*

By October 2015, the OPHC engineering team had set-up a series of component of the physical network infrastructure. This included the Wi-Fi network, the optical network, the layer-2 switch network[22], and the Millimeter Wave[23]. These components belonged to different parts of the three networks that were described in the vision statement (**Figure 21**: 110). For example, the Wi-Fi and Millimeter Wave belonged to the wireless network, Wireless Mile (see ② in **Figure 21**: 110), and the optical network is another name for the 144 core fibre network (see ① in **Figure 21**: 110).

(2) Developing a platform

Alongside setting-up the physical infrastructure, David also worked on designing a platform for the physical infrastructure. The platform is an important part of delivering a programmable infrastructure. Without it, setting up heterogeneous physical networks merely creates an ordinary network infrastructure which 'prescribes' some network functions. People cannot conduct further re-configurations. To build a platform, David first sought to design a roadmap to guide the innovation directions. However, he was not able to convince the OPHC management to agree to the roadmap. Then, he started to work at a more practical level: designing the High-Level Architecture (HLA). The HLA is the crucial part to build a platform. However, the design of the HLA was not straightforward and required a lot of experimentation. As I mentioned above, there was no model for the engineers to work from and they had to design the platform from scratch. To provide readers with an idea of what it means for a High-Level Architecture (HLA), I have reproduced a version of the HLA based on David's presentation in **Figure 22**.

[22] It is a data link layer of a network, usually is Ethernet.
[23] It short for mm Wave. This is the band of radio spectrum between 30 GHz and 300 GHz. It can be used for high-speed broadband access.

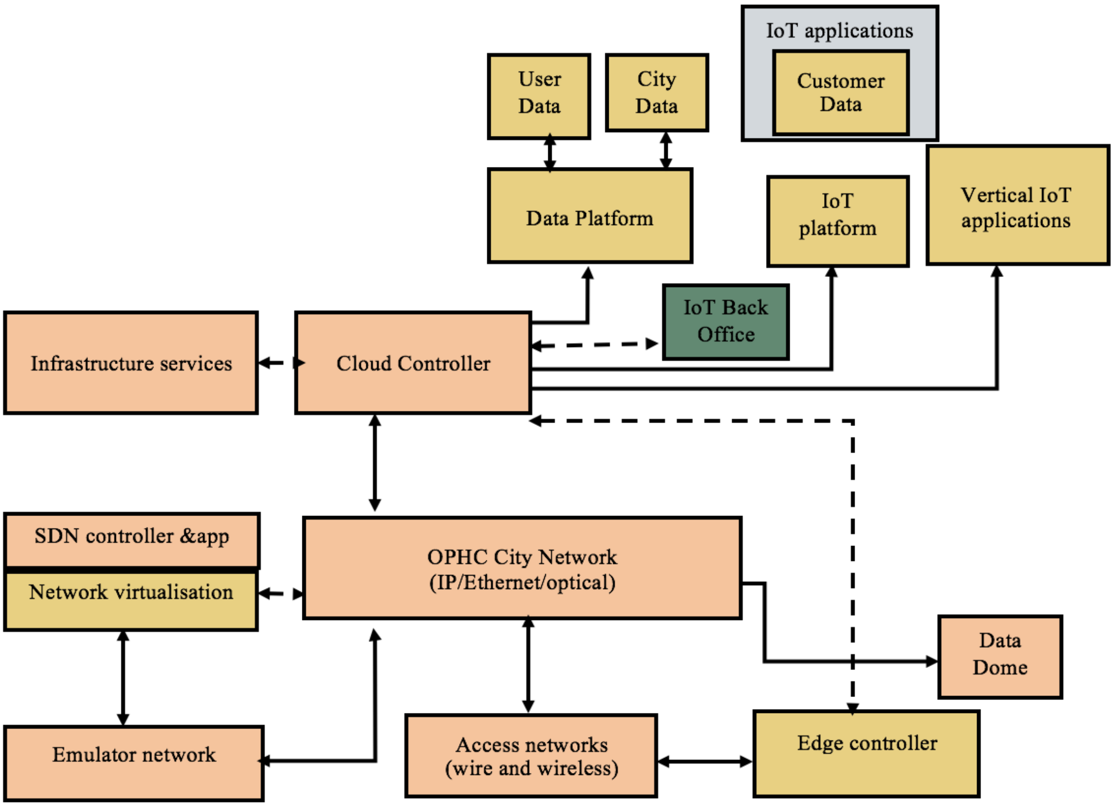


Figure 22. *A version of the High-level Architecture produced by David in September 2016 (The light salmon boxes in the figure refer to already finished designs, while the other boxes are functions that were under development.)*

When designing a HLA, the OPHC engineering team had some basic ideas about what kind of features they should include (e.g. a SDN controller[24]), but they did not have a precise agenda. So, they assembled whatever technological components were available for them in the process. For example, the cloud controller was not included in the original idea. But during the engineering process, the engineering team realised that it would be possible for OPHC to provide cloud services, so they added the cloud environment to the HLA. Another example is the 'edge computing'[25]. The idea of incorporating 'edge computing' existed at

[24] The SDN controller is logically centralised controller to manage the hardware components within a network. It provides a platform to develop different application on top of it, and passes their results to the components through the interfaces using a standardised protocol. It enables the behaviour of the components and control the network based on an intelligent manner.

[25] What is 'edge computing'? A good way to understand 'edge computing' is to compare it with "cloud computing". Cloud computing centralises computing power and data in cloud and delivery on demand computing resources and services over the Internet on a pay-as-you-go basis. It is often hosted in big data centres which distributes it around the world. "Edge computing" does the opposite. It pushes applications and computing power away from centre. This enables analysis and data gathering at the source of data.

the early stage of the platform development, but it was formally added to HLA in February 2016. The rationale to incorporate edge computing in OPHC was that it might enable creative digital workers in Harbour City to do creative things, such as enabling initiatives like the 'Fun City'[26]. Why did the engineers constantly modify the design? This reflects an engineering philosophy called "*technology agnostic*" that is shared by some engineers of OPHC. The "*technology agnostic*" approach means that when engineers design an infrastructure, they do not just 'prescribe' functions, but also want to build a "live" infrastructure that can constantly integrate different types of the latest technologies into it. In another words, an infrastructure is not only designed for today, but can also constantly adapt to tomorrow's needs. As David comments, "*whenever something is useful and available, it has to be integrated as part of the platform*" (Interview with David, 10 September 2016).

From the engineering story of building a programmable infrastructure, we can see that the vision of OPHC has a role to play in the process. It *coordinated* the OPHC engineering team's actions towards realising the programmable infrastructure. David and the team took up the role that the vision of OPHC assigned to them and gradually built agendas to realise it. However, the testbed had not been properly designed due to the funding deadline. The engineers had to connect the physical components as well as design the platform (e.g. HLA). So, on one hand, they created task divisions to set-up a series of physical infrastructures. On the other hand, they sought to develop a platform to control the physical infrastructure and made it programmable. The work of setting-up the physical network was easier than the development of the platform. This was partly because the management did not have an agreed idea about what the project's priorities were. It was partly because of technological bugs that the engineering team met in the process. For example, they developed several versions of the SDN controller. It was partly because of the engineers' ambition to keep the programmable testbed state-of-the art. As a result, the OPHC engineering team successfully developed some aspects of the programmable infrastructure, such as a Wi-Fi network, an optical network, an SDN controller, and a cloud service, but, at the time of this writing, they had not been able to deliver the programmable testbed.

[26] Fun City is a local initiative generated from the DOCK. It aims to use digital technology to help people interact with each other and interact with the urban infrastructure.

6.1.2 The actual users of the Programmable Testbed

The vision of a programmable testbed imagined that an ecosystem of users could use it. The vision statement of OPHC specifically *scripted* four categories of users, including academic researchers, business communities, local host partners, and other cities (Chapter 5). However, during the observation period, the vision statement only mobilised two categories of users to use the OPHC infrastructure. They were the research and business community. Below, I provide more information about both types of users. I will explore why other user categories did not experiment with OPHC in other parts of this thesis (see more in section 6.2, section 6.3, and Chapter 7).

(1) Mobilising the academic users

The vision of OPHC successfully mobilised some researchers to use the experimental testbed. Those researchers were mainly engineers who come from the NEXT Lab and Harbour City University. They took the roles that the vision of OPHC allocated to them and conducted various experiment with the OPHC testbed, ranging from big European research projects to small research projects in the NEXT Lab. For clarity, I list those research projects in **Table 3**. As we can see from the table, there are three types of research projects that use OPHC testbed and I use colour to distinguish them. The first type is EU research projects. From September 2015 to July 2016, engineers in the NEXT Lab submitted several bids to the European Horizon 2020 project. In those bids, they all included the element of the OPHC testbed as part of the proposal. In the end, four bids were successfully allocated funding. The second type of research project was existing research projects in Harbour City University. One example is the QCT project which was carried out by the quantum computing research group in Harbour City University. It uses the OPHC testbed to test its quantum key distribution (QKD[27]) knowledge. The third type of research project was a small research carried out by researchers in the NEXT Lab. There were two examples. One was an urban traffic control project. The researcher Charlie wanted to use OPHC's RF Mesh network to collect the data about the vehicles on the road. He chose OPHC's RF Mesh network to conduct the experiment because it is more redundant than normal Wi-Fi network. Another example was an urban mobility pattern analysis project carried out by researcher Carlo[28]

[27] QKD refers to quantum key distribution. It is a network security skill which uses quantum mechanics to guarantee secure communication.
[28] Carlo left the NEXT Lab at the end of 2016.

from the NEXT Lab. The project wanted use OPHC's cabinets to install equipment to understand people's mobility patterns in cities.

Table 3. *The Research use of OPHC*

Project type	Title of the research	The reason to use OPHC infrastructure
EU project	European 5G project	Using OPHC test-bed to evaluate the optical and wireless elements of 5G technologies.
EU project	COPY	Using OPHC infrastructure to test smart city applications such as, smart energy and smart transportation.
EU project	BALL	Using the heterogonous network infrastructure of OPHC to test the converged optical and wireless networks.
EU project	EDGE	Using OPHC infrastructure to explore big data and cloud computing
University of Harbour City	QCT	Using OPHC infrastructure to test quantum key distribution (QKD).
Lab research project 1	Urban traffic control	Using OPHC's RF mesh network to collect data about vehicles.
Lab research project 2	Urban mobility pattern	Using OPHC's cabinets to conduct real-life experiment.

However, as we might notice already, the vision of OPHC only mobilised certain groups of researchers and they were all engineers. The vision of OPHC was not able to mobilise non-engineer researchers, such as social scientists. In other words, there is a gap between the OPHC testbed and non-engineer researchers. The issue of engaging non-engineers (e.g. social scientists) was put on the agenda at the beginning of the project in 2015. OPHC specifically recruited a researcher to explore what kinds of social research and civic innovation that might be facilitated by OPHC and how non-engineer researchers could be engaged. In the end, the researcher found that there was no one on the social science side of Harbour City University who could lead the smart cities research, so, she recommended that a multi-disciplinary collaboration (social scientists and scientists) is required on the topic of the smart city.

(2) Mobilising big corporations

The vision statement of OPHC also mobilised business groups of users to use OPHC. The OPHC business team took the responsibility to align big corporations to use OPHC. Chris was in charge of the business team and Rufus joined him in 2016. At the end of the fieldwork (October 2016), the OPHC business team had successfully aligned three big corporations for OPHC, including, a SDN expert company JEP, a mobile technology company EXTRA, and a communication device/service provider NORMAN (**Table 4**). There are at least three different reasons behind why these big corporations were willing to partner with OPHC. The first reason is that they wanted use OPHC's testbed to test their products. For example, JEP uses OPHC infrastructure to develop its waste management system. The second reason was to sell their smart cities applications back to Harbour City Council. This is especially the case with JEP. As a member of OPHC business team comments, "*Strategically what JEP wants to do is conduct development for their product and co-engineer across the network. But, they also want to sell their products back to the City Council…*" (Interview with a member of OPHC business team, 23 August 2016). The third reason was to raise the companies' reputations in the smart city world. This motivation can be seen in the case of NORMAN. As a member of the OPHC business team said, "*they [NORMAN] want to associate with a global smart city innovator (Harbour City and OPHC). That means NORMAN is in the smart city world*" (Interview with a member of OPHC business team, 23 August 2016). It is worth noting that NORMAN is not the only company who has this mindset. There are a "*pipeline*" of technological companies who want to partner with OPHC for this purpose.

Table 4. *Big corporations partnered with OPHC*

Big business partners	The reason to partner with OPHC
JEP	Testing its waste management system through OPHC. Regarding the connection with OPHC as an opportunity to sell its solutions back to the Harbour City Council.
EXTRA	Testing its technological solutions in a real-life environment.
NORMAN	For the purpose of public relationship.

Similar to the research use of OPHC, only certain people within the business category could use OPHC. As we can see above, the three aligned companies were all big businesses and there were no SMEs or independent developers to conduct experiments through OPHC. This is not what the vision of OPHC had originally imagined. The vision statement of OPHC envisaged a wide range of businesses who could experiment with OPHC, ranging from large international telecommunication corporations (e.g. JEP) to small start-ups in the Harbour City (e.g. SMEs in the BOX and DOCK) (see more in Chapter 5). Why was the vision of OPHC not able to mobilise SMEs and developers? Based on my interviews with various developers in the field, I have identified three reasons.

First, most SMEs do not have ready-to-experiment technologies. Take the BOX for example, according to the vision statement of OPHC, SMEs in the BOX can use OPHC infrastructure to test their technologies, ranging from technological readiness level one (technologies close to market) to technology readiness level nine (technologies that are far from market). However, what has happened in reality is that most SMEs in the BOX are start-ups. If we put them on the technology readiness scale, they might belong to technology readiness four or five (Interview with Sam, 15 August 2016). Although the vision statement suggested that all business readiness levels can test their products through OPHC, in reality most companies were not at the stage to test their products.

Second, the lack of middleware stops developers using OPHC. What is middleware? It is a piece of software that abstracts all technological details and network resources. The abstraction helps users who are not network experts to interact with network resources. In the vision statement, developers who have certain technological skills are considered more likely to use OPHC infrastructure than average citizens. However, these developers are not communication network experts and they do not know how to interact with OPHC infrastructure without middleware. This was reflected in an interview with a local developer:

JW: *Do you know SDN?*

A developer: *I do not know who wants to mess with that level of things.*

JW: *Without that level of understating, do you think it is possible for you to use it?*

A developer: *Yeah, I guess to have this virtual machine and cloud is my normal way of doing things. Any extra work for me to use it are barriers. I do not want to understand the way they build their network or anything like that. What is the benefit for it?*

Interview with a local developer, 03 October 2016

As the interview above shows developers do not want to make any efforts to understand network knowledge in order to use OPHC. So, there needs to be 'middleware' between developers and the OPHC infrastructure. However, according to David, this 'middleware' is not going to be built in the near future. This is because 'middleware' is normally specific to applications. For example, a 'middleware' for telehealth management is different from a 'middleware' for energy management. Since there is no specific application build on top of the OPHC infrastructure at the moment, the OPHC engineering team have not considered developing middleware as a priority.

The third reason is that SMEs and individual developers tend to think of the short-term future. Unlike large companies and research communities who can spend 3 to 5 years conducting development, SMEs and start-ups cannot afford to wait and invest their time in experimentations. What they want is the "future now". SMEs tend to invest in something that can pay back very quickly. As one developer expressed it, "*I think experiments are more appealing to bigger businesses, because they can think ten years. So, I think for us, we need to survive in the next two or three years. It is much shorter-term thinking*" (Interview with a local developer, 03 October 2016). Large companies can think about the longer-term future; although experiments do not bring them any immediate benefit, they can still invest time, money, and the workforce to do it because they will get a return in the future. We can see an example of this thinking, the case of MiniCat later (see section 6.3).

6.1.3 Learning, pressure, and innovation outcomes

The development of the open programmable infrastructure and the alignment of users were not separate activities. The interactions between users and the OPHC engineering team also generated impacts on the overall development of the project. The effect was both positive and negative. The positive effect refers to learning process that was triggered by interactions. Learning is one of positive effects that nurture a novel innovation. According to Strategic Niche Management (SNM), learning is one of three niche internal development mechanisms. Hoogma (2000) further distinguishes learning as *first order learning* and *second order learning*. *First order learning* means learning that accumulates knowledge for pre-established assumptions. While, *second order learning* refers to learning activities that challenge the initial cognitive frames. Both types of learnings can be identified in this interaction process. *First order learning* covers many aspects. For instance, the OPHC engineering team learned many things about users' needs, such as how the infrastructure can better fit into users' test requirements. The OPHC business team learnt how to deal with some tricky issues while cooperating with partners, such as the issue of copyright[29]. This type of learning enriched the programmable infrastructure in terms of its design and project management skills. *Second order learning* happened occasionally in the process. One good example is that it triggered OPHC business team to re-think the business model. In the initial business model (**Table 2**), large corporations needed to pay membership fees to use the OPHC infrastructure. For example, OPHC's first business partner JEP paid £1 million in membership fees in five years to use the OPHC infrastructure. However, through observing the interaction between JEP and the OPHC infrastructure, the OPHC business team gradually realised that the initial business model was not fair for OPHC because the membership fees were very low compared with the amount of money big companies were going to make from experimenting through OPHC. So, they learned from the real experimental experience and this learning challenged their original assumption of the business model. At the time of this writing, the OPHC business team had already started to re-design the business model for OPHC.

The interactions between the users and infrastructure also generated negative effects to the OPHC infrastructure development. This was mainly due to the increasing workload it brought to the already busy engineering agenda. I visualise the engineering team's workload in **Figure 23**. As we can see from the figure, apart from the workload of developing a platform, the engineering team also had to make sure that the infrastructure supported the partners' experiment requirements. As a result, between the end of 2015 and the early part of 2016, the OPHC engineering team faced a heavy workload. At its peak time, there were five engineers who dealt with both the engineering work and user commitments. However, two engineers left the OPHC engineering team in early 2016. The number of engineers reduced from five to three people making the engineering work difficult to carry on. So, in May 2016, David made a decision to stop the engineering work because it was impossible for three engineers (including himself) to deliver the programmable infrastructure, to support research projects, and to fulfil the contract commitments to the partners. In the interview, David used the phrase "*engineering freeze*" to describe the pause of engineering work (Interview with David, 10 September 2016). The imbalance between too much user

[29] In order to cooperate with partners, the engineering team had to open up some of OPHC's technologies. So, there was a dilemma between protecting copyright and collaborating with others.

commitment and too few engineers shows that there was a lack of coordination between the OPHC engineering team and OPHC business team. The OPHC business team focused on aligning business partners. But it should have been more aware of the availability of the engineering team. Otherwise, the alignment of users would cause stress for the OPHC engineering team and delay the overall project.

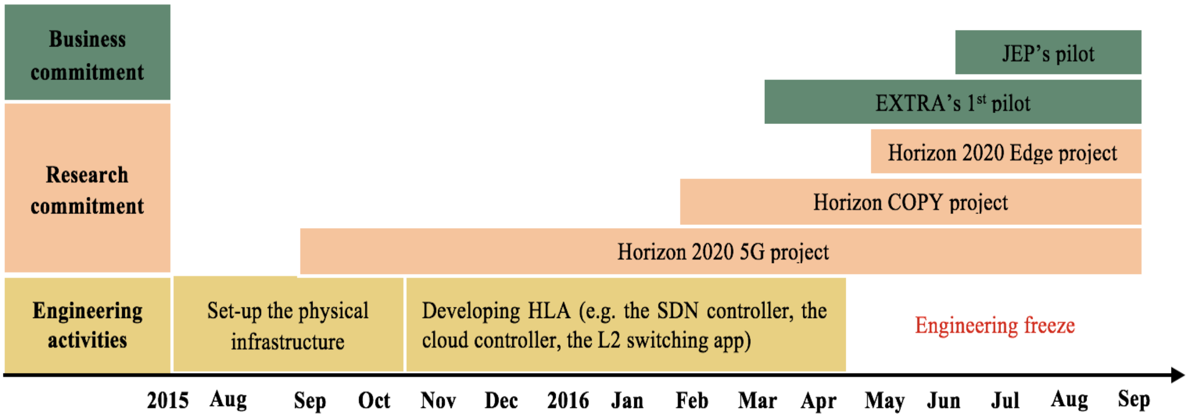


Figure 23. *The workloads of OPHC engineering team*

At the end of the period of fieldwork (October 2016), neither the infrastructure development or the user engagement had realised the vision of making an open programmable testbed. It could not be considered open because only certain people used it; mainly engineers and big corporations. Although the engineering team had set-up most parts of the physical infrastructure of OPHC and developed some aspects of the HLA, the testbed was not fully programmable. However, the experiment of delivering an open programmable infrastructure is not seen by the OPHC team as a failure. I will elaborate on this point in the discussion section.

6.2 Making the first application Data Dome

6.2.1 The expectation of the Data Dome

The second OPHC related innovation activity that I am going to talk about is the making of OPHC's first application, Data Dome. Before we go into detail about the actual implementation process, it is necessary to revisit the expectation. In the vision statement of OPHC, the Data Dome was described as an urban data visualisation device (see Chapter 5). To help readers better understand this expectation, I visualise the idea in **Figure 24**.

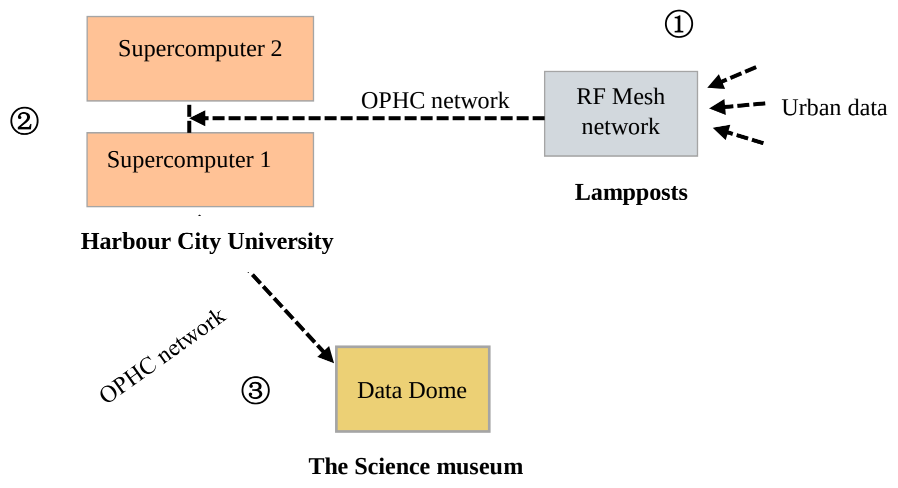


Figure 24. *A scenario for Data Dome*

As we can see from the figure, sensors hung on the lampposts in Harbour City created an RF Mesh network. They harvest real-time data in the City (see ①). This data will be collected and passed to supercomputers in Harbour City University. Supercomputers have the capacity to process and draw 3D visualisations about the real-time data (see ②). Then, the data visualisation will be streamed to the Data Dome through OPHC's high speed fibre network (see ③). Susan used air pollution data as an example to help people at an event imagine this idea.

> *"To give you, for instance, an example of a use case. We have connected this digital visualisation facility [Data Dome] to pollution monitoring sensors, and to the supercomputer on the other side. So, we are going to be able to actually collect pollution data in real-time. Analysing and processing the data in real-time. The supercomputer is actually able to create 3D visualisation of this pollution levels in the city at the same time. So, somebody that is going to enter this visualisation facility [Data Dome] is going to be able to see how pollution in the city evolves in real-time and they are going to be able to interact with this as well eventually."*
>
> *Susan presented at a 5G conference, March 2015*

The Data Dome is important for the OPHC not because it is a data visualisation device. More importantly, it carries out OPHC's citizen engagement mission. As the interview extract above shows the OPHC wishes citizens to enter the dome and interact with urban data. The reason the dome was assigned for this function was because of its location in the Science Museum. It was seen as a public place that citizens can access and come to engage with the urban data visualization (Interview with a member of Data Dome team, 23 February 2016; Interview with Brown, 10 May 2016). It is worth noting that the Science Museum is actually a private space that citizens have to pay to enter.

6.2.2 The implementation process of the Data Dome

In order to materialise the expectation of the Data Dome, a Data Dome team was formed. The team consisted of several innovators from two institutions: The Science Museum and the Harbour City Council. Harbour City Council were interested in the Data Dome because it was the fund holder of the project. From a civil services point of view, it wanted to understand how the immersive environment of the dome can trigger emotional responses of citizens to make changes (Fieldnotes, 24 May 2015). And how the Data Dome can create more jobs for local people. This Science Museum sent staff to the project because the dome is the property of the museum and it regarded the Data Dome as an opportunity to upgrade its dome facility (Interview with a member of Data Dome team, 05 October 2016).

(1) Configuring the physical features for a Data Dome

Similar to the OPHC engineering team, the Data Dome team also had to design and implement the idea from scratch, because there was nothing like the Data Dome available on the market to be purchased and installed. But compared with the OPHC engineering team who were technology specialists, the Data Dome team did not have Dome related background knowledge, such as data visualisation or data analysis. So, the Data Dome team had to rely on advice from different experts all the way through the innovation process. They first decided to configure the physical features of the Data Dome. They replaced the old optical projection system[30] with a 3D digital projection system that was provided by a digital planetarium solution provider called Digital Moon. The projection solution consists of two projectors, 17 computers, and an archive of planetarium show contents. There were two reasons to choose the Digital Moon's solution. First, Digital Moon is an expert planetarium show equipment provider and its solution satisfied the Science Museum's long-time expectation of upgrading its dome. Second, the solution could provide two projectors to create a 3D dome[31].

[30] The old projection system was a "starboard" projector (See more in Chapter 5).
[31] In order to project 3D images, there need to be two digital projectors.

The purchasing of the Digital Moon system took a step closer to the expectation of making a Data Dome, because the dome could now be used to view digital contents. The Data Dome team were excited to take the next step which was to explore what types of data can be visualised in a dome environment. They commissioned I-LOOK, a digital content design company, to explore the possibilities. The research output ends up with a beautiful trailer video of OPHC (**Figure 25**). This video optimised 300 data-sets in Harbour City, including, environmental, public service, and transportation data. The video seeks to demonstrate that various types of urban data can be viewed in the dome. However, the trailer video was merely a film of data visualisation, not the real-time data visualisation that was envisioned by OPHC. As a member of the Data Dome team comments, "*I-LOOK did great work. But the practicality is that if you want to do data visualisation. You cannot make a film about that data visualisation because it is not up-to-date. You want the data visualisation to be immediate, relevant, and able to adjust. It is not a film. It means interactive, and that's really the journey we started to explore interactivity*" (Interview with a member of Data Dome team, 20 October 2016).

Figure 25. *People viewing the trailer video of OPHC in the Dome*

Based on I-LOOK's research, the Data Dome team soon realised that they needed to explore the interactive aspect of real-time data projection (Interview with Peggy, 05 October 2016). However, the Digital Moon system does not support interactive content. I-LOOK suggested buying additional servers. The innovation team took the advice and purchased two servers from a provider calls WISO. The choice of WISO was not random. Innovators thought that the WISO system might enables developers to produce contents for the Dome because WISO supports the game development platform Unity[32] and this might help to attract local creative content developers.

We have seen that the vision of OPHC (especially its expectation of a Data Dome) has a role to play. It *coordinated* the Data Dome team's actions. The Data Dome team bought in to the expectation of the Data Dome and sought to configure physical features for a Data Dome. It was not straightforward to find the right components to build a Data Dome. In order to nurture this new idea, two niche internal mechanisms can be identified in the process. One is *building social networks* around the expectation. As we can see from above, the Data Dome team aligned a series of technology providers around the expectation, such as Digital Moon, I-Look, and WISO. Those actors contributed their products to make up the physical aspect of the Data Dome. Another mechanism was *learning*. There were some *first-order learnings* (Hoogma, 2000) that can be identified in the process. For example, the Data Dome team gained technology related knowledge about the Data Dome, such as the kind of server enables it to display creative content, and how to use WISO to project the interactive contents. As a result of this stage of exploration, the Data Dome team assembled various components to make up the Data Dome. **Figure 26** illustrates the different components that made up a Data Dome. As we can see from the figure, the key elements of the Data Dome are distributed in two rooms. Room 1 is a display room which contains a sphere dome screen, around 90 seats, two digital projectors, and two computers. The Room 1 connects to the Room 2. In Room2, there are 17 computers from Digital Moon, two WISO servers, and an OPHC 'active node'. The Digital Moon's 17 computers are mainly used for the planetarium show, while the WISO servers and the 'active node' are prepared for the purpose of the Data Dome.

[32] Unity is a platform that many developers use to design creative contents, such as Virtual Reality contents and games.

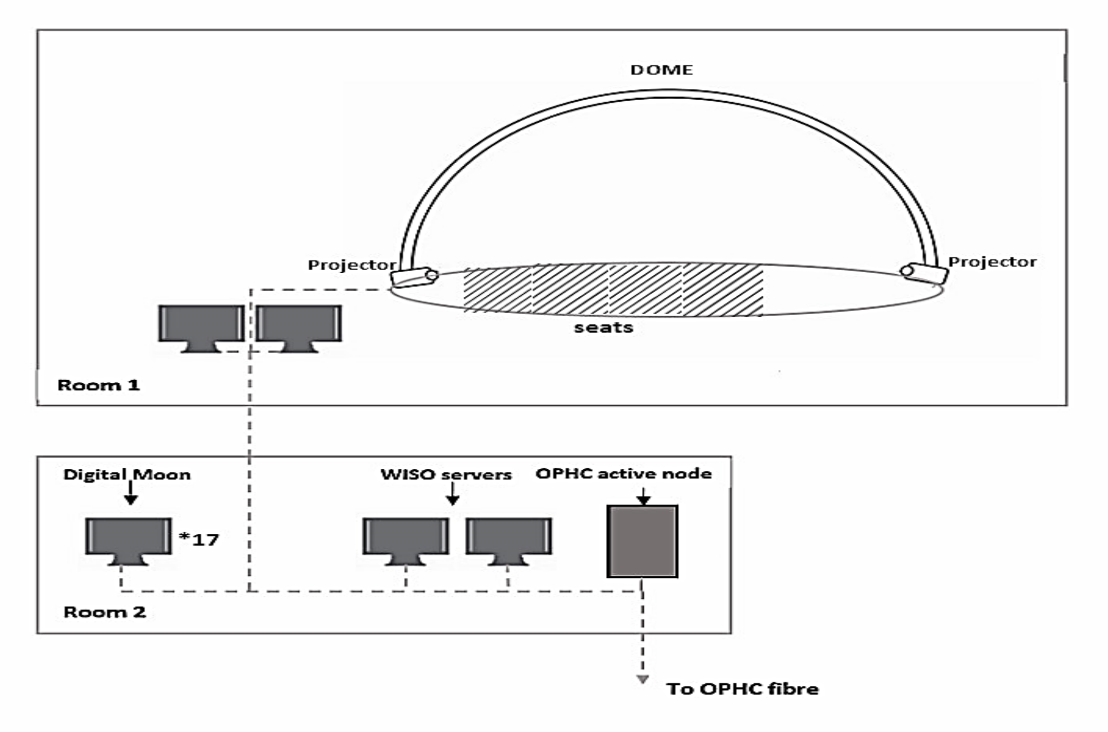


Figure 26. *The physical layout of the Data Dome*

(2) Data Dome workshops: seeking content for the dome

After roughly figuring out the physical features of the Data Dome, the Data Dome team decided to move to the next stage which was to explore suitable content for the Dome (Interview with Peggy, 05 October 2016; Interview with Jim, 20 October 2016). Several actors from the DOCK and Future City Radar (FCR) also joined this stage of the exploration. DOCK is a local digital centre who has rich experience in fostering creative projects. It assigned one member of staff to the Data Dome team. Future City Radar (FCR) is a UK government supported agency who is keen to work with local cities to find good smart cities demonstration cases. Data Dome attracted FCR's attention and it sent several members of staffs who understand data to the Data Dome team.

In order to find good real-time data contents to project in the dome, the Data Dome team decided to open-up dialogue with wider groups of people in Harbour City. Workshops were regarded as the best way to foster this dialogue. In the end, two workshops were hosted between May 2015 and July 2015. The workshops attracted around fifty people from various fields in Harbour City, including data visualisation, digital art, games (especially the virtual reality[33] game), and data analysis (Fieldnotes, 24 May 2015). In order to align actors, niche internal mechanism *articulation of expectation* can be found at the beginning of each workshop. The mechanism of *articulating expectation* is supposed to contribute to attracting resources and necessary support for the Data Dome (Schot and Geels, 2008). Speeches were the main method of articulating the vision of Data Dome. In many speeches, the Data Dome was introduced as part of the city-scale OPHC infrastructure. Participants were encouraged to use available open data to design creative content that reflected urban issues (Fieldnotes, 24 May 2015). £60.000 of prize money was prepared by FCR for successful prototypes.

The activities in relation to the *articulation of expectation* and the prize money motivated many people to participate at the beginning of the workshops. Participants came up with many ideas about what could be done in a dome environment. Below, I have provided extracts from two interviews with workshop participants. They provide us with an idea about those imaginations. The first idea comes from a data analyst. He wanted to develop a system for the dome that allowed the dome to run different types of data. The second idea comes from a programmer who wanted to make the dome a space for people to discuss data collectively.

Designing a system for the Data Dome

> *"You can say to the dome, 'dome, show me a graph of X against Y', and then the graph appears above your head. You just speak, command, and it shows the graph above your head. And you can go like that [wave hand], then the graph disappeared. And there is a Twitter stream about people's discussion alongside it. You can sort it when it [data] moves towards you. Like the Minority Report. When you are finishing looking at the data, and you said, 'we should have a vote. Who think this is useful?' People put their hand up, and it counts automatically…"*
>
> *Interview with a data analyst, 13 September 2016*

Data Dome as a place for collaborative discussion about data

> *"My expectation is that it could be a great shared space where people could do data visualisation and talk about data visualisation. I hope it could be a very social space to discuss data (…). I thought it could be an open space that it could have three or four data visualization distributed in the dome (…). Maybe a group of 3 or 4 people, wondering around and talking about the visualisation. They can also walk across the room and have discussions with*

[33] It is a computer generated simulated scenario that can be interact with by a person using specific input devices, such as handles or gloves with sensors.

> *another group. At the moment people often look at data on their laptops in their office. There is no human contact and it is a very lonely experience (...).”*
>
> *Interview with a programmer, 05 October 2016*

Although there were many great ideas about what could be done in the dome environment, only a few developers sent their bid documents to the steering group and two unfinished prototypes won the competition. One prototype was a planning tree game that allowed audiences to interact with contents on the dome screen with their phones. This interaction aims to increase people’s environmental consciousness. The real-time data in this prototype came from audiences’ real-time input, but it is worth noting that this data was not coming from the OPHC’s RF Mesh network. Another prototype was a 3D data visualisation of urban air pollution. The prototype would extract data from a platform called open data street map[34]. Then, it built a model of Harbour City and visualised the pollution levels in Harbour City. In this prototype, there were no significant interactivity functions. It did not use the RF Mesh network either.

Why was the alignment of local developers not very successful? One reason is the insufficient *articulation of expectation*. It was insufficient for two reasons. First, there was a contradiction between *saying* and *readable action*. What is *readable action*? According to Van Lente (1993), vision statements are not only *words* that can be read, but also actions that can be interpreted. He calls these non-words vision statement as *readable action*. Similar to *words*, *readable action* also does something by positioning itself, others, and artefacts. When articulating the expectation of the Data Dome, on the one hand, the Data Dome team used their speeches (*words*) to encourage developers to conduct development for the dome. While on the other hand, their actions manifested in reality, showed the opposite. The contract that they sent to participants said that the copyright of the successful bids and all its products would belong to the FCR. The *readable action* in the contract contradicted what innovators had told the developers about IP arrangement at the beginning of the workshops. The contradiction confused developers. The data analyst that I mentioned above, had planned to develop a system for the Data Dome, but he lost the motivation when he read the copyright arrangement. He did not want to develop a system which would allow FCR to make money from it. Another workshop participant felt the same, as he comments “*if they tell us it is a commission for FCR, that is fine. But they did not tell us, until I read the contract I started*

[34] See more in https://www.openstreetmap.org/about

to realise that (…)" (Interview with a workshop participant, 03 October 2016). As a result, the contradiction between *saying* and *readable action* put off lots of potential developers, and not many people submitted bids to the steering group. Another reason for the insufficiently *articulated expectation* was the level of *interpretation flexibility* the expectation left for people. According to Schot and Geels (2008), expectation should leave a certain degree of *interpretation flexibility* for people. If the interpretation is too narrow, it cannot encourage people to participate. If it is too general, it cannot provide guidance for research directions. In this instance, innovators did not provide enough space for workshop participants to interpret the idea. As we can see from the two interview extracts above participants had many ideas about what could be done in the dome. However, Data Dome innovation team overly focused on finding suitable prototype contents for the dome, rather than opening it for other interpretations. As a result, very few people signed up to the idea of the Data Dome.

Apart from insufficient *articulation of expectation*, other practical reasons also restricted the formation of networks to produce content for the Data Dome. First, developers were given a very short time to develop prototypes and there was no skill training for conducting developments in a dome environment. As a result, developers spent a great amount of time learning how to use the technologies before being able to develop content. For example, it took participants a long time to find out how to synchronise content from two projectors. Second, there was limited time for people to get into the dome is used for the planetarium show during the daytime (9 am - 5 pm) (Interview with a member of the Data Dome team, 23 February 2016; Interview with a workshop participant, 13 September 2016). Third, the layout of the dome restricts human movements, because there are around 90 seats and many steps in the dome (see **Figure 26**). So, any design ideas that involved body movement in the dome would be restricted by this layout.

(3) Launch event: enrolling potential users

After finding two possible prototypes, the Data Dome team started to prepare for the official Data Dome launch. They aimed to attract clients to hire or conduct development for the dome. When preparing contents to show at the launch event, they gave additional money to two prototype developers to let them finish their designs. However, neither prototype was able to present at the launch event due to unexpected technical issues. The Data Dome team quickly found an alternative content from a designer in the DOCK (**Figure 27**). The OPHC engineering team and the OPHC business team also joined the preparation work. The OPHC engineering team connected the Data Dome to the OPHC infrastructure. Chris structured the price system for the Data Dome which is £1000 per hour. He also persuaded a big company H&C, a British multinational company, to use the Data Dome. In the end, H&C made a 3D video about its aircraft engine to present in the dome.

Figure 27. *Dome content made by a developer in the DOCK*

The launch event of Data Dome was hosted in a winter night in November 2015. When audiences walked into the Dome, they saw a live video streaming in the dome. In the video, two engineers from the NEXT Lab were talking to them in real-time (**Figure 28**). For most people, the experience might feel like no more than making a long-distance Skype call. However, from an engineering point of view, the streaming was significant! To send high-resolution live video from the lab without compressing requires a lot of bandwidth. The live video successfully demonstrated the capacity of the OPHC network (Interview with David, 15 September 2016).

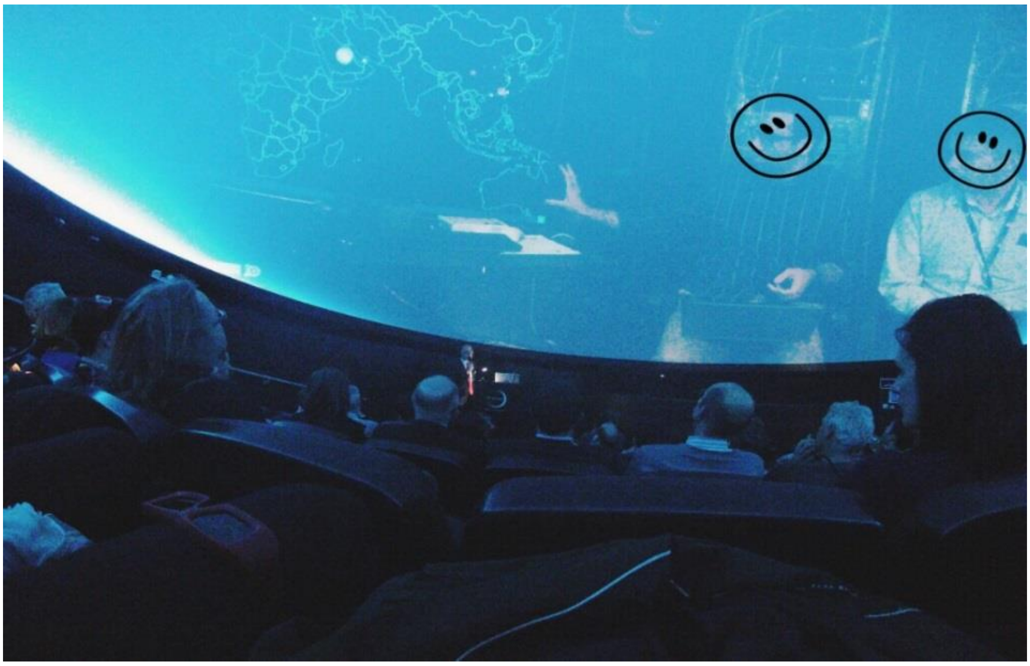


Figure 28. *Audiences watched live video in the launch event (The smiling faces are applied to anonymise engineers' real identity)*

Before viewing the pre-arranged contents, Chris tried to use his speech to articulate the expectations of Data Dome. He told audiences that the Data Dome was the first 3D Dome in the UK, that it was part of the OPHC project and that it was connected to OPHC through the high-speed network. This idea also attracted some interest from big companies, such as H&C. People were welcomed to use the dome and it would cost people £1000 an hour to hire it.

However, the *articulation of expectation* suffered. Through interviews with the audience and Data Dome team it was clear that not too many people bought-into the expectation. In reflecting on the failure in *articulating the expectation*, a member of the Data Dome team commented:

> *"The launch event suffered because we have no story sorted out. One day, we said to developers that we want developers for this project. And all the stuff we show really was quite experimental. On the other hand, it was really expensive [to hire the place]. And we did not seem a match-up between audiences. What we say is not developed enough to say to corporate clients 'look at the stuff we can do'. It also was saying to developers you cannot afford to. Also, OPHC has not figured out how to sell the Dome (...)."*
>
> *Interview with a member of Data Dome team, 20 October 2016*

From the comment above, we can see that there are two reasons that affected launch event participants buy-in to the expectation. One reason is that the pre-arranged contents were not convincing enough for corporate clients to invest. Another reason is the contradiction between *saying* and *readable action*. In Chris's speech, he encouraged people to hire the dome. But, most developers cannot afford to pay £1000 per hour to rent the dome. As a result, they felt the expectation of Data Dome was not an invitation for them. Instead, it seemed to say, "*you are welcome if you can afford it*" (Interview with a member of Data Dome team, 20 October 2016).

(4) May Digital Week: enrolling VR and 360-Degree content developers

The Data Dome team learned many things from the launch event. They conducted a series of *first order learning* which was mainly about project management. For example, they learned that the Data Dome should be free for developers to experiment with their designs and there should be more time for developers to conduct experiment in the dome. They also identified the most easily aligned group for the dome which were the Virtual Reality and 360-degree content[35] developers. Moreover, they noticed that there needed to be tools to make it easier for those developers to produce content for the dome. I will return to the tool later.

Apart from accumulating knowledge to achieve the goal of the Data Dome, the Data Dome team started to realise that the expectation of the Data Dome as an urban data visualisation device to engage citizens would be difficult to achieve. From an infrastructure design point of view, the Data Dome was not built for real-time data coming through the RF Mesh network and waiting to be projected onto the dome. Instead, it was an opportunity to build. Therefore, the OPHC infrastructure was not intentionally set-up for the purposes of the Data Dome. From a citizen engagement point of view, the Data Dome as a public space to engage citizens was challenged. First, the dome is a public space, but it is not an open public space that people can access at any time. In the daytime, the dome's purpose is to serve the planetarium show. So, there is only a short time in the day for people to view data. Second, not everyone in Harbour City can enjoy the data show. Because the dome is located in the centre of the Harbour City, making it difficult for people who live in other parts of city to access the dome. Moreover, even if people can travel to the dome, seeing some air quality

[35] An immersed spherical content (e.g. video).

data fly over their heads is not going to have a great impact (Interview with a member of Data Dome team, 05 October 2016). However, the "not right" feeling was not strong enough to challenge the original assumption of the Data Dome, and generate *the second order learning*.

Although the innovation results were not positive, the Data Dome team did not claim the project is as failure. Instead, they decided to continue the experiment and build an agenda to align Virtual Reality and 360-degree content developers. In order to encourage them to develop contents for the Dome, the Data Dome team removed the entrance barriers that had been identified in the previous stage. For example, the Science Museum agreed to make the dome free for developers to conduct development. They also built tools to bridge the VR/360-degree contents and dome contents (Interview with a member of Data Dome team, 05 October 2016). As we can see above, VR/360-degree content and the dome content both share a developing tool Unity. However, the projection environment of the dome is different from the projection environment of a VR device. So, in order to make Virtual Reality and 360-degree content developers more willing to develop content for the dome, the Data Dome team decided to develop conversion tools that can easily convert VR/360-degree contents into dome contents. Moreover, they specifically commissioned a local VR company (Orbit Game[36]) to design a game demo. This ended up with a VR game called Splat Harbour City. Audiences can download an application on their phones and play the game collectively with other people in the dome (**Figure 29**).

[36] The reason to choose Orbit Games was because the company has a second screen technology (the dome could be regarded as the first screen and the phone screen as the second screen). The second screen technology allows participants in the dome to use their phones as input devices to interact with content on the dome.

Figure 29. *Audiences playing Splat Harbour City in the Dome*

These efforts of this new approach were presented in an annual digital event in Harbour City called May Digital Week. The Data Dome team tried to articulate expectation again at this event. Compared with the launch event, the message sent out at this event was very clear. The central message was that the dome welcome developers in local communities to conduct development. As one member of the Data Dome recalls, "*this May event is trying to re-structure the story around the dome and say to digital communities that we want to make this dome for you to use. We have stopped talking about products and big prices. This is a development project and we want you to come to the Dome*." (Interview with a member of the Data Dome team, 20 October 2016)

However, the event was still not able to align developers to make content for the dome. As another member of the Data Dome team commented, "*people do VR, we said to them could we just transfer stuff you do into the dome? They said no. So, sometimes this tool might help, but the question for them is why I am going to do that?*" (Interview with a member of Data Dome team, 05 October 2016). The interview with Tim from the Orbit Game provides insights to help understand why developers were not make content for the dome:

***JW**: Are you going to continue do something for the Dome in the future?*

***Tim**: These types of project (Data Dome) are good. But, we are doing business. I want to know the product that I made. How much is it going to sell? How much it costs me to make it? To make a demo is fine [Splat Harbour City]. But, (smile), if I spend one year to develop some excellent product in the dome, how can I recover my cost and who going to invest in it?*

An informal interview with Tim, 15 May 2016

So, although the conversion tool exists, VR entrepreneurs have tended to make a rational decision not to develop VR content for the dome. This resonates with the findings in the previous site that developers were less likely to test through OPHC because they tend to think short-term in order to survive.

Despite the unsuccessful alignment of developers, the action of lowering the entry barriers has gradually fostered an ecosystem around the dome. This ecosystem consists of a wide range of actors, such as big corporations (e.g. MiniCat, UK BROADCAST), local institutions (e.g. Straw House), and individuals (e.g. artists, scientists), etc. Apart from MiniCat who developed a gesture control application for the Data Dome, other users all creatively used the dome to suit their own private expectations. For example, UK BROADCAST uses the dome to further their knowledge of the 360-degree video. Straw House uses the dome space to conduct an art performance (**Figure 30**). A medical scientist hired the dome for a Virtual Reality Brain lecture. Visual artists use the dome for art performances and so on. The case of MiniCat is special. MiniCat is a U.S multinational technology company who sent eight engineers to design a gesture control application for the dome (See appendix 8 (3)). The reason MiniCat conducted development for the dome for free was because the company is big enough to invest money long-term and do charitable work to increase the company's public reputation. But, most other developers use the Data Dome for their own purposes. To see actors freely translate the dome according to meet their individual expectations is fascinating, because it demonstrates that local people can creatively make use of local assets. But for the expectations of Data Dome, too much *interpretation flexibility* might influence the innovation direction. As discussed above, too little and too much *interpretation flexibility* is not good for an innovation (Schot and Geels, 2008).

Figure 30. *People playing balloons inside the Dome*

6.2.3 Innovation mechanisms and results

The stories above presented the implementation process of the Data Dome. The vision of OPHC coordinated the Data Dome team's actions. They built agendas gradually in the process. For example, they started with configured physical features for the Data Dome. Then, they hosted workshops to seek contents for the dome. They also made efforts to align clients and developers for the dome. During the process, three niche internal mechanisms helped to build up a protected space to experiment with the idea. As we see above, innovators built a network of suppliers for the Data Dome (e.g. Digital Moon and WISO) and aligned developers around the dome (e.g. the developers for two prototypes). The Data Dome team attempted to attract resources through articulating the expectation of the Data Dome. However, it was not very successful due to the contradiction between *saying* and *readable action*, and the lack of *interpretation flexibility*. The Data Dome team also achieved a lot of *first order learning*. That *first order learning* formed a positive feedback loop which allowed innovators to adjust their actions in the innovation process. There are some *second-order learning* in the process. For example, the Data Dome team noticed the initial assumption of the project might not work. But, their doubts were not able to challenge the original assumption of the project.

Similar to the previous site, the vision of OPHC was not able to coordinate actions among the Data Dome team, the OPHC engineering team, and the OPHC business team. As we see above, the three teams only briefly cooperated in the launch event. The lack of coordination between the Data Dome team and the OPHC business team ended up with the announcement of a price that people could not afford. This eventually influenced the articulation of vision. The lack of coordination between the Data Dome team and the OPHC engineering team made the Data Dome a dead end. As we see above, the innovation results in this site were an upgraded 3D Dome and several prototypes of content. The innovation results were far from realising the original expectation of the Data Dome that was scripted in the vision of OPHC. I have visualised the innovation results in **Figure 31**. As we can see from the figure, there was only a high-speed network connecting the dome to the OPHC infrastructure, there was no real-time data collecting from the RF Mesh network or calculating by the supercomputers. To better understand the actual relationship between the dome and the OPHC infrastructure, I would like to provide an analogy of a glass and a pipe[37]. If we say the dome is a glass. Then the high-speed network between the NEXT Lab and the dome could be regarded as a pipe. All the prototype content displayed in the dome were like pouring different types of water into the glass (the dome) to let people see that it is possible to have water come through the pipe. However, in fact there were no real water running through the pipe into the glass. The water poured into the glass was just a way to demonstrate what would happen *if* there were water running through the pipe. In order to make the dome a data visualisation device for the OPHC infrastructure, there needed to have been coordination between the development of the Data Dome (Data Dome team) and the development of Programmable infrastructure (OPHC engineering team). For instance, OPHC's RF Mesh network would need to be open for people to hang different type of sensors on the lampposts to collect real-time data. The collected data would be analysed by the supercomputers before being streaming to the dome. Although the OPHC vision coordinated innovation activities within each site, it was not able to coordinate innovation activities *between* sites. I will explore what I call the *paradox of vision* later. Similar to the previous site, although the niche experiment of the Data Dome was not able to deliver the original expectation of an urban data visualisation device, the Data Dome project was not seen to be a failure. A series of negative experiments results were interpreted as obstacles that could be overcome in the future. I will further elaborate the point of failure in the discussion section.

[37] This metaphor was inspired by the discussion with my technology consultant Dr. Grandet.

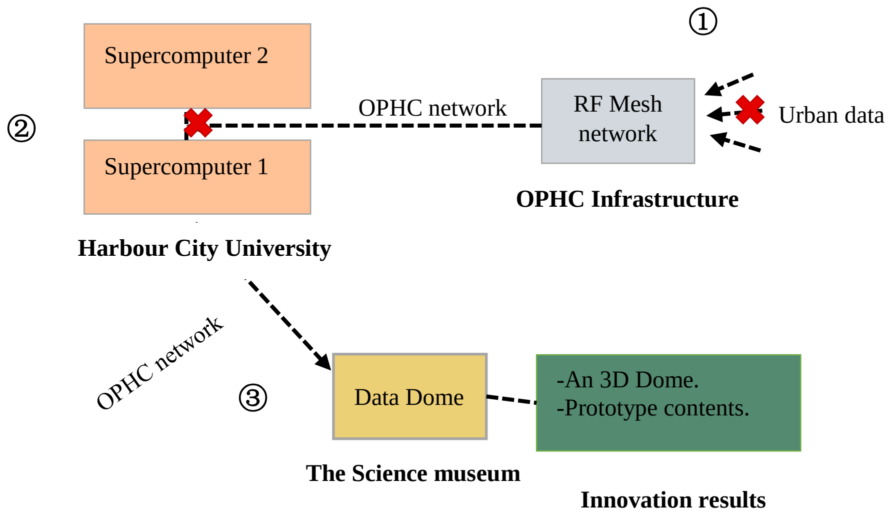


Figure 31. *The innovation results of the Data Dome*

6.3 Making the Citizen Sensing application (Toad)

6.3.1 Straw House buy-in to the vision of OPHC and creating a guiding expectation

(1) Straw House buy-in to the OPHC vision

The last OPHC innovation activity in relation to implementing OPHC I am going to talk about in this chapter is the making of a Citizen Sensing application. This application was co-produced by Straw House and local communities. Before describing the innovation process, I will briefly introduce how Straw House joined this journey. The OPHC vision statement imagined the local community organisation Straw House [38] co-producing an OPHC application with citizens. The vision statement did not say exactly what the application would be, it indicated that Straw House could take up this role. Straw House has a long history of using media as a tool to engage citizens (Interview with Camila, 30 June 2016). In the past twenty years, it carried out a series of technological projects with local communities (Interview with Stein, 28 June 2016). Following the global trend of the smart city, Straw House has recently developed an agenda to explore the element of citizen

[38] Straw House is based in the southern part of Harbour City a place recently faces with many challenges, such as in health, education and employment.

engagement in a smart city. This agenda naturally led them to the idea of smart citizens. As Stein, a co-director of Straw House, emphasised, "*you cannot have a smart city without smart citizens*" (Fieldnotes, 24 February 2015). The organisation also actively participated in the negotiation process of the Super Connected City (SCC) competition. So, it witnessed how Gigabit Harbour City morphed into OPHC. Although neither directors of Straw House were quite sure about what a programmable infrastructure was, they still decided to take on the role that OPHC assigned to the organisation.

Opportunity and fear were two reasons why Straw House decided to buy-in to the vision of OPHC. On the one hand, Straw House heard that OPHC regarded citizen engagement as one of its principle aims. Straw House has many years of experience of working with local communities. Straw House naturally thought it could contribute its expertise of citizen engagement to OPHC. On the other hand, the *image pressure* (Konrad, 2006) of OPHC made Straw House worried not to be part of it. Straw House heard that many important local institutions (e.g. the Harbour City University, DOCK, BOX, and Science Museum) had all signed up the OPHC project and were having OPHC's physical nodes installed in their buildings. A sense of not wanting to fall behind made Straw House also want to become a local partner. One co-director of Straw House expressed the anxiety of not being a part of the OPHC project, "*you have to be at those tables and say, 'I want one of those nodes, please'. You have one in Harbour City University, and you have one in the DOCK. You have one in the BOX. You have one in the Science Museum. OK, now you have one in the Straw House*" (Interview with a co-director of Straw House, 30 June 2016). This phenomenon is similar to Konrad's (2006) observation about e-commerce. She found that large numbers of companies signed up to the vision of e-commerce not necessarily for specific benefits from the business, but often, because they were following collective expectations. Collective expectations can produce *image pressure* which motives actors to engage in collective expectations. Based on this observation, Konrad (2006) argues sometimes actors sign up a vision not because they could benefit from it. Instead, they are influenced by the *image pressure* that caused by the collective expectation. In line with Konrad (2006), I argue that because many main actors in Harbour City signed up to the vision of OPHC, this made OPHC a collective expectation at the local level, and this collective expectation created *image pressure* for Straw House. This *image pressure* made Straw House feel obliged to become a part of the vision and request to have an 'active node' installed in the organisation.

(2) Creating a guiding expectation: A commons approach of Citizen Sensing

After Straw House bought-into the vision of OPHC, it needed to build an agenda and take actions towards realising the role that OPHC vision assigned to it. Camila started to think about what kind of technology could easily to engage citizens. She began to pay attention to off-the-shelf sensor technology and wanted to develop a citizen sensing application for OPHC. In an international living lab meeting, she met a PhD researcher from Barcelona called Maria who was doing research about technology and citizens. Camila invited Maria to Harbour City to help Straw House to develop the Citizen Sensing project. Maria accepted the offer and mapped out the worldwide Citizen Sensing project for Straw House.

Maria's research informed the expectation formation of the Citizen Sensing project. In order to build a unique Citizen Sensing project. Straw House needed to find a guiding expectation and this expectation should have an underpinning value that would appeal to local communities. In the end, they highlighted the philosophy of the 'commons' as an underpinning value. Although there is no agreed definition about what a 'commons' is, Straw House defined 'commons' as resources that people create based on collective agreement. The resources will also be used for the common good (a leaflet produced by the Straw House, 2016). Wikipedia is often used as an example to explain the idea (Fieldnotes, 05 March 2016). As Maria explained at one event, "*It is like Wikipedia, one person builds the infrastructure, and nine people edit things. Then, you get ninety people who use it. All those people are vital for the ecology*" (Fieldnotes, 19 April 2016). The idea of a 'commons' was adopted by Straw House and it became the core value for the expectation of the Citizen Sensing project. This expectation was called *a commons approach to Citizen Sensing*. It hoped that people from different backgrounds would come together to co-produce something for the common good.

6.3.2 Producing a Citizen Sensing application

Following the expectation of a *commons approach to Citizen Sensing*, Straw House started to take actions to produce the application. Several staffs from Straw House formed a Citizen sensing team, including Camila, Stein, Judy, Lucy, and some other member of staff from Straw House. As with the Data Dome, the Citizen Sensing project was also a novel innovation idea in Harbour City. So, it required a protected space (*niche*) to be built around the expectation as well. However, it was worth noting that this *niche* is slightly different from the Data Dome *nich*e, because it was formed by a community organisation. Grin et al, (2010) argue that *niche*s can not only be formed by policy makers, but also by social groups, such as community organisation. Citizen Sensing is a bottom-up *niche* that was created by a community organisation. Compared with *niches* formed by actors in authorities, *niches* formed by community organisations have different characteristics in their internal process. I will address those characteristics within the context later.

(1) Identifying problems and network formations around the expectation

In winter 2015, the Citizen Sensing team decided to identify problems that mattered to local people and could be solved by sensor technologies. They conducted a broad city-wide network analysis. They talked to people in local barber shops, laundries, and community centres, etc. In the end, they came up with three local issues that could be addressed by sensing technologies: *biodiversity and health, the use of the high street*, and *issue of damp in houses*.

Then, the Citizen Sensing team started to form social networks around Citizen Sensing. Building social networks around innovative ideas is important for developing a *niche* because actors in the social networks can provide necessary resources to the project, such as money, people, expertise to support the realisation of the expectation (Schot and Geels, 2008). Network formation is especially important for *social niches* (Verheul and Vergragt, 1995) like Citizen Sensing project, because unlike *niches* formed by big business or policy makers that can easily access many resources, *social niches* relies more on volunteers to bring a mix of skills and resources (Seyfang et al., 2014). In the case of Citizen Sensing, Straw House uses a social networking event and workshops to foster social networks around the Citizen Sensing project. Within those events, many artistic methods were applied to help identify the skills and capabilities of participants. For example, at a networking event in January 2016, Judy designed a big eyeball like wall chart and hung it in the entrance hall of Straw House (**Figure 32**). The chart was divided into different section and each section indicated aspects that participants could offer to the project, including development, workshops, commons license. When participants walked into Straw House, they were asked to cover the chart with pink post-its. Those pink post-its helped Straw House to spot local talent within participants and build up a network of useful skills for the projects.

Figure 32. *Using a big wall chart to identify available resources within local communities*

(2) Articulating expectation and learning

In the Spring 2016, Straw House ran a workshop to refine issues and build alliances. The workshop attracted around 60 people from different sectors. At the beginning of the workshop, Judy, Lucy, and Maria tried to use speeches to *articulate the expectation* of Citizen Sensing. This helped to attract the necessary support. Below, I have provided an extract of their speech:

> *"So, why we are here? I guess the starting point is that I believe people really have a minimal role in how we design and imagine our cities. The real danger at the moment is that we have got a command and control vision of what a smart city is going to be. Energy, water can be sucked into private corporations and big government. Really not too many spaces left for human agency and imagination. So, commons approach to Citizen Sensing, we really have to do a bottom-up approach for the smart city and think about what are tools? and what kinds of issues people care about at their community level (…). In the spirit of 'commons', a large part of this project is to create participatory urban 'common' where citizens generated data becomes a 'common' good for cities…"*
>
> *Fieldnotes, 05 March 2016*

As we can see from the fieldnotes, when introducing the expectation of Citizen Sensing, the Citizen Sensing team illustrated the negative aspects of main stream smart city making which is dominated by the "*command and control*" of big corporations and has little space for "*people's imagination*". To provide an alternative, the project suggested a commons approach to smart city making that aims to co-produce smart applications for local communities. The introduction of the 'commons' as the core of its expectation contributed to articulating the vision of Citizen Sensing in two ways. First, the 'commons' as a value is important for a *niche* that is to be built by social groups. As Verheul and Vergragt's (1995) research shows, bottom-up niches built for social organisations always contain some values. They call these *social niches*. *Social niches* may not be primarily based on the profitability future. Instead, their expectations are to pursuit some other values. For example, in their study, they find that environmental awareness is the core value of expectation in their studies and it helps to motivate actors to participate in the project (Verheul and Vergragt, 1995). In the same vein, Citizen Sensing is a bottom up *social niche*. The alignment with the value of 'commons' shows the organisation's intention to incorporate social value to the project. This helped the project to build alliances. Second, the concept of 'commons' moralised the vision of the project. As Berkhout (2006) points out "*vision of future tends to be moralised*". People often use positive moral value or visualise the negative consequences of not doing it to persuade people to sign up to a proposed vision. This is especially the case with Citizen Sensing. As we can see from empirical data above, the Citizen Sensing team talked about the negative consequences of current mainstream smart city making, and then they suggested a commons approach to Citizen Sensing.

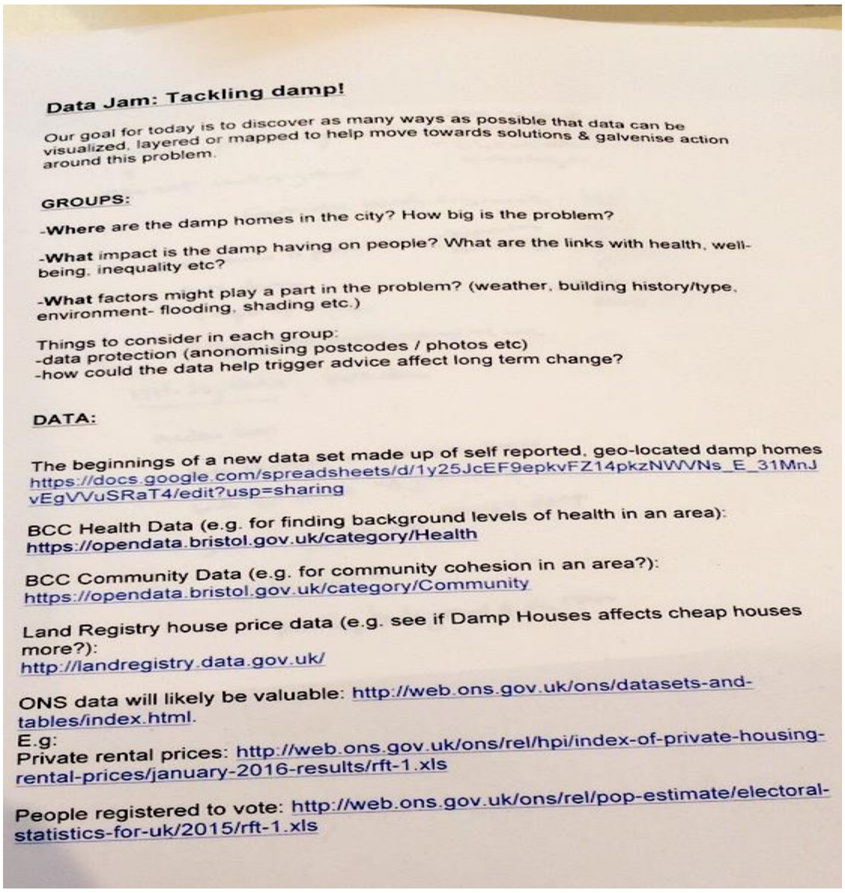
The moral values associated with 'commons' were very important for Citizen Sensing team to articulate the expectation of the project. Participants found the idea of 'commons' hard to understand at the beginning. But through an iteratively articulated process, the expectation was gradually accepted by some people as an interview with a workshop participant shows, "*I did not get [the idea of commons] the way at the start, but the more I learn it, it sounds very appealing (…). The main reason I like it is because it thinks about people's role. For example, they break down this commons approach. People are sort of data contributors. That is a personal role. We found, I cannot remember the name, the person does the networking thing. The person does the funding. In the beginning, I did not get it, but in the process, I get it*" (Interview with Zack, 03 October 2016). So, in general, the *articulation of expectation* in this setting was quite successful. It helped to attract many participants to follow the Citizen Sensing innovation process.

After the *articulation of expectation*, participants were also encouraged to express their ideas about the data and the project. Then, they were divided into three groups to discuss three pre-established issues: *the biodiversity and health*, *the use of the high street*, and *the issue of domestic damp* (**Figure 33**). Much *first order learning* could be observed in the process. The Citizen Sensing team accumulated many ideas that shaped their future agendas. For example, based on notes and observations from the workshop, the Citizen Sensing team realised that the issue of damp in homes attracted more interest than the another two. So, they decided to narrow down the focus to build an application that tackled this issue.

Figure 33. *Participants were discussing the issue of damp*

(3) Designing an application for the issue of damp

After narrowing down the focus, the Citizen Sensing team hosted a workshop in the summer of 2016 to develop a sensing application for the issue of domestic damp. Based on the previous event, a specific social network was formed around this issue. This included people who have damp houses, data analysts, big landlords, programmers, etc. In the workshop, participants talked about the issue of damp, relevant sensors technologies, scenarios, and possible design (see more details in **Figure 34**). In the end, two types of data were identified relevant to the damp issue: indoor temperature and indoor humidity level. In order to collect those two types of data, a temperature sensor and a humidity sensor were chosen by workshop participants as the most useful (**Figure 35**).



Data Jam: Tackling damp!

Our goal for today is to discover as many ways as possible that data can be visualized, layered or mapped to help move towards solutions & galvenise action around this problem.

GROUPS:

-**Where** are the damp homes in the city? How big is the problem?

-**What** impact is the damp having on people? What are the links with health, well-being, inequality etc?

-**What** factors might play a part in the problem? (weather, building history/type, environment- flooding, shading etc.)

Things to consider in each group:
-data protection (anonomising postcodes / photos etc)
-how could the data help trigger advice affect long term change?

DATA:

The beginnings of a new data set made up of self reported, geo-located damp homes
https://docs.google.com/spreadsheets/d/1y25JcEF9epkvFZ14pkzNWVNs_E_31MnJvEgVVuSRaT4/edit?usp=sharing

BCC Health Data (e.g. for finding background levels of health in an area):
https://opendata.bristol.gov.uk/category/Health

BCC Community Data (e.g. for community cohesion in an area?):
https://opendata.bristol.gov.uk/category/Community

Land Registry house price data (e.g. see if Damp Houses affects cheap houses more?):
http://landregistry.data.gov.uk/

ONS data will likely be valuable: http://web.ons.gov.uk/ons/datasets-and-tables/index.html.
E.g:
Private rental prices: http://web.ons.gov.uk/ons/rel/hpi/index-of-private-housing-rental-prices/january-2016-results/rft-1.xls

People registered to vote: http://web.ons.gov.uk/ons/rel/pop-estimate/electoral-statistics-for-uk/2015/rft-1.xls

Figure 34. *Questions discussed in the workshop*

Figure 35. *A box of sensors displayed in one damp workshop*

After a series of learning episodes around the damp issue, another workshop was hosted to create a sensing application for the issue. Only a local freelance data analyst, John, turned up to the workshop with a technological design. John's design was informed by a series workshops. He showed his design to other participants and this design was quickly adopted as the prototype without facing any competitions. A curious incident occurred at the workshop which determined the look and the name of the sensing device. John put the Raspberry Pi[39] and its box together on a table (**Figure 36**) and a workshop participant accidentally put two paper eyes on the box. This made the box look like a Toad. Participants agreed that the shape of Toad was suitable for a damp sensing device because "*toads normally live in a damp environment*" (Interview John, 13 September 2016). Then, a designer from the Straw House helped to craft the look of the Toad. Finally, the Toad became the result of the project (**Figure 36**).

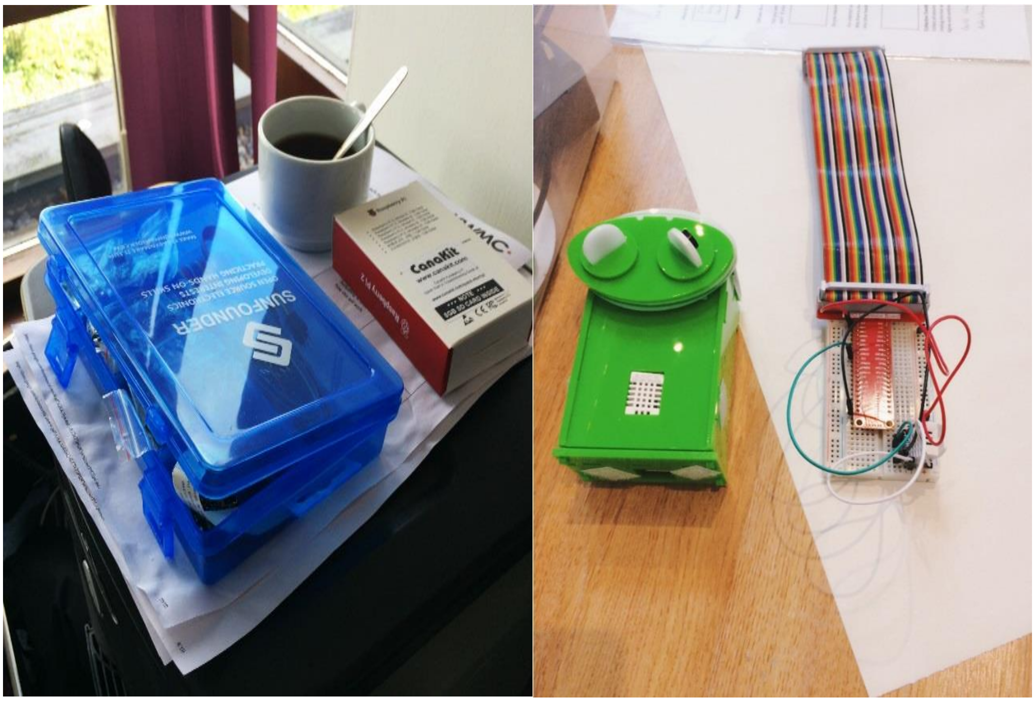


Figure 36. *John's sensor box and Raspberry Pi (Left) and the Toad (Right)*

(4) Seeking to deploy the Toad

After configuring a sensing device, the natural next step was to find people with damp houses willing to accept the Toad to collect data for two weeks. In order to find local houses to

[39] It is a tiny and affordable computer that can be used to learn programming.

participate in the experiment, Straw House turned to its own social networks. Straw House has good pre-existing connections in the city, and this network made it easy to quickly identify and bring together people with certain skills, and knowledge (Martiskainen, 2016: 13). In the end, Straw House contacted one of its previous partners, a local energy company, to find damp houses in local communities. A man from the local energy company called Michael, who had 30 years working experience in the social housing, heard about the Citizen Sensing project and shared the aspiration of the project. Through his social network, he found five houses in local communities that were willing to experiment with the Toad.

Because the Toads were not connected to the Internet, John went to each home to upload the data manually two weeks later. The question in front of John was what if there were more Toads in people's home in the future? It would be impossible to upload the data manually. So, the Toads have to connect to the Internet to upload the data automatically. Wi-Fi was one way to connect the Toad to the Internet. However, about 30 per cent of households in the eastern part of Harbour City do not have Wi-Fi. The lack of Wi-Fi in these residential homes made John look for the alternative network, the RF Mesh network. The RF Mesh network is a communication network using radio frequency to send data. So, he thought if he put an RF card in the Toad, the Toad could send data to the RF Mesh network even for families without internet connections. So, this meant the Toad could be used in almost all areas in Harbour City.

Since Straw House became one of the local host partners of OPHC, it always had the idea of utilising OPHC infrastructure. At the beginning of the Citizen Sensing project, Straw House had the idea that Citizen Sensing could generate an application for the OPHC. The interview extract below captures how a co-director of Straw House perceived this opportunity:

> **JW**: *When you launched the citizen sensing project, did you have an idea to use the OPHC infrastructure or not?*
>
> **Stein**: *I think so, we already started to use the Data Dome (...). For us, the question is how we can use it [OPHC] rather than what will happen. We were told it [the OPHC infrastructure] would be there. So, what the application of that within a community context will look like? What does it mean?*
>
> *Interview with Stein, 30 June 2016*

But Straw House did not know what application it was going to produce and how it might use the OPHC infrastructure. Straw House had a meeting with Harbour City Council at the beginning of the Citizen Sensing project. One question from Harbour City Council was how could the Citizen Sensing project utilise the existing City Council infrastructures? Given OPHC is a joint venture between the Harbour City council and Harbour City University, OPHC was naturally on the list of City Council's infrastructures. For Straw House, the questions were "*what kind of things might mean the need to create lots of sensors for people to use and how can the RF Mesh network support it? What kind of licenses and protocols would put in place?*" (Interview with Judy, 09 July 2016) These questions were brought up many times by Judy during the workshops. However, how to use the OPHC infrastructure was not clear until the Toads were placed in residential homes to collect data.

In order to find an RF Mesh network in Harbour City for the Toad to use, John immediately thought about the OPHC's RF Mesh network. According to the official OPHC website, the RF Mesh network was supposed to open in April 2016. John had a high expectation of using the OPHC's RF Mesh network because he had heard that there was around £20,000 for companies to use OPHC's RF Mesh network (Interview with John, 13 September 2016). But in summer 2016, there was still no news about the OPHC RF Mesh network's opening. In order to confirm the launch date of the OPHC's RF Mesh network, John contacted Chris. Through Chris, he found out that the RF Mesh network would be installed in August 2016. And, John started to sketch a plan about the Toad and the RF Mesh network. I still vividly remember the moment that he illustrated his plan to me in a pub. He thought the Toad could connect to the OPHC RF Mesh network in the autumn of 2016. However, his dream was shattered when he heard that Chris had resigned, and the launch date of the RF Mesh network had become uncertain.

The official explanation about the delay of opening the RF Mesh network was because the RF Mesh network solution provider Gold Autumn was very protective about its technology. It was not willing to open its RF Mesh for OPHC to re-configure and make it programmable. What Gold Autumn's RF Mesh solution could do was to remotely control streetlights. According to the OPHC's vision, the RF Mesh network should become a programmable network that would allow users to integrate whatever sensors they want. In order to find a compromise between Gold Autumn's solution and the engineering vision of the RF Mesh network, the OPHC engineering team came up with an idea to build an IoT Router[40]. At the end stage of fieldwork, the OPHC engineering team were still at the stage of testing the IoT Router.

6.3.3 The innovation results and the issue of lack of coordination

Citizen Sensing team successfully *articulated the exp*ectation to its audiences from local communities and attracted many interests and supports. A specific social network formed around the project, including developers and people who have damp issue. The learnings from the workshops help the Citizen Sensing team to narrow down the research direction to the damp house and sensor technology. Through John's personal experiment and Straw House's design, the Toad was produced as an outcome of *niche* experiment. The Toad was a potential to bridge the Citizen Sensing project and OPHC. However, the Toad also brought up the tension between Citizen Sensing and OPHC infrastructure development. This because although there was an existing application, people still cannot use the OPHC infrastructure.

Why could the Toad not use OPHC's infrastructure? In appearance, this was because Gold Autumn was not willing to open up its technology for the OPHC engineering team to reconfigure. But the deeper reason behind it was that there was no coordination between the innovation activities of the programmable infrastructure (the OPHC engineering team) and the innovation activities of Citizen Sensing (the Citizen Sensing team). As we saw in section 6.1, the OPHC engineers conducted experiments on the infrastructure. They built agendas for the infrastructure development and continued to update the agenda to keep it state-of-art. However, people normally understand OPHC through its marketing agenda produced by the OPHC business team. The marketing agenda circulated in public mainly through the official website. According to the OPHC marketing agenda, the IoT Mesh (another name for the RF Mesh network) should have launched in April 2016. The marketing agenda was created at the beginning of the project. To some extent, it was how the OPHC business team envisioned what the OPHC platform could provide as marketing products. As seen above, what coordinated John's expectation was this marketing agenda of OPHC, not the engineering agenda of OPHC. We can also see above, that John received information about the RF Mesh network either through reading the official website online or chatting with a member of the

[40] Through the bridge an IoT Router, the IoT Router seeks to make the RF Mesh programmable. The idea is that one end of the IoT Router would connect the RF Mesh. And people can add whatever sensors they want to the network at the other end (Fieldnotes, 14 September 2016).

OPHC business team. However, the messy engineering process and continually evolving engineering agenda were never reflected in the marketing agenda. I visualise the lack of coordination in **Figure 37**. As can be seen from the figure there were no linkages or communication channels between the OPHC engineering agenda and OPHC's marketing agenda. As a result, Straw House's innovation activities were coordinated with the OPHC's marketing agenda and not with the engineering agenda. This is why the development of the Toad was faster than the infrastructure development and the Toad was not able to connect to the OPHC infrastructure. The Toad not being able to use the RF Mesh network generated disappointment for Straw House and other participants. I will come back to the point of disappointment in Chapter 7.

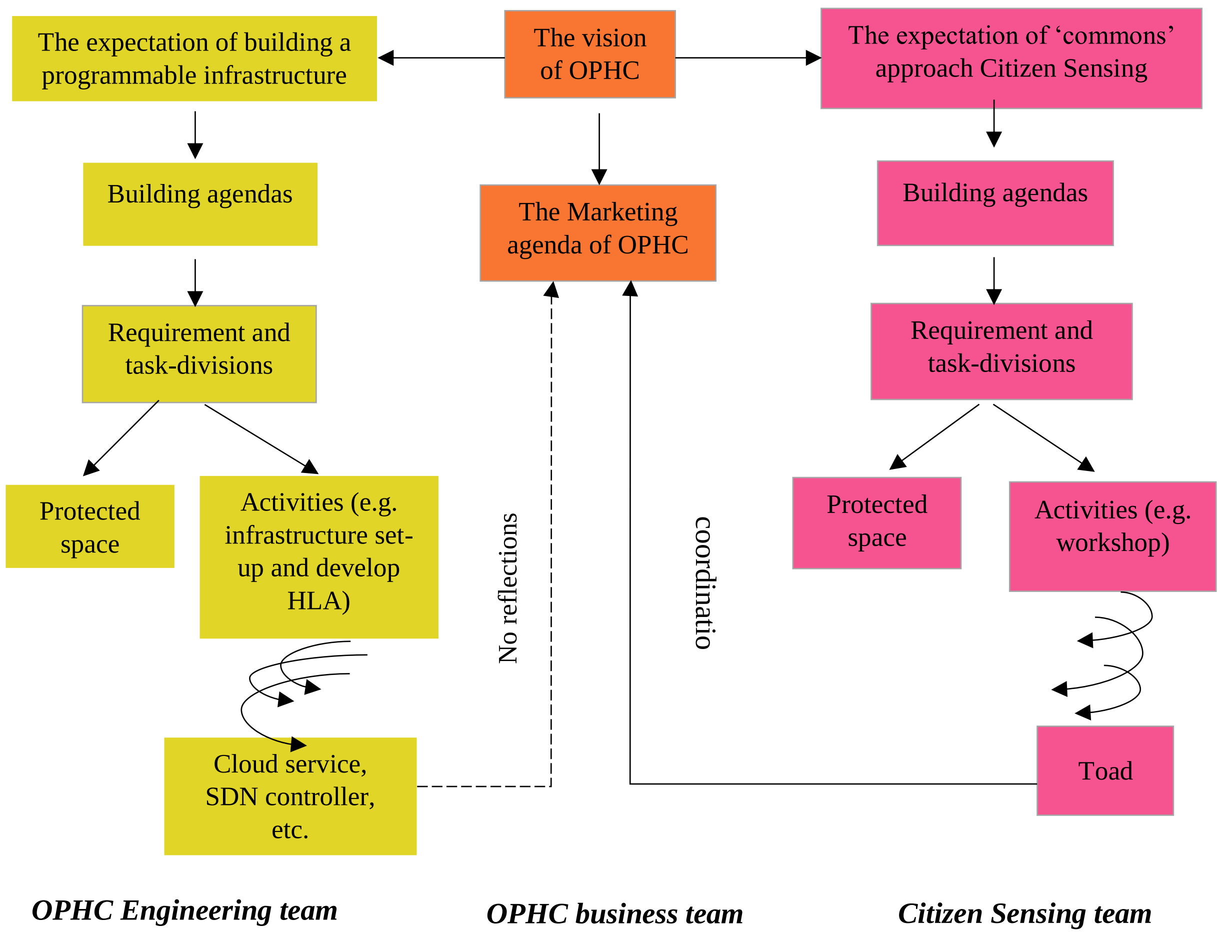


Figure 37. *Understating the lack of coordination between Citizen Sensing innovation and OPHC infrastructure innovation*

6.4 Discussion

This chapter has investigated the roll-out of the vision of OPHC. The research shows that the implementation of OPHC occurred in three parallel sites in Harbour City. Above, I have drawn on relevant conceptual tools to conduct some analysis about innovation activities in each site. Below, I would like to look across the three sites to summarise four key features in the implementation process. These are innovation mechanisms, the role of vision, the challenges of citizen engagement, and the "impossibility" of failure.

6.4.1 The three parallel niche experiments

From the empirical data above, we have seen that the materialisation process of OPHC happened in three parallel sites: a programmable infrastructure, an urban data visualisation application Data Dome, and a Citizen Sensing application. The programmable infrastructure and the Data Dome are features that were *scripted* in the vision of OPHC. In the case of the Citizen Sensing project, Straw House took up the role that the vision of OPHC allocated for it and tried to enact it. If we say that OPHC is a local smart city *niche*, then the three innovation activities can be regarded as three *sub-niches* of OPHC. They are *niches* because they were all protected spaces (*niche*) formed by different innovators (OPHC engineering team, OPHC business team, Data Dome team, and citizen sensing team) around novel ideas. We can refer them as *sub-niches* because they were all protected by the overarching *niche* of OPHC.

In order to experiment with those three novel ideas and attract resources around the ideas, the three *niche* internal processes (*articulation of expectation, building social networks*, and *learning*) were found in all three sites. For example, innovators trying to *articulate expectations* in order to attract attention. They all sought to form social networks around the ideas and conducted many levels of learning. Those niche internal mechanisms contributed to nurturing innovation in three sites. They helped the innovators explore three novel ideas, but not all the mechanisms were conducted properly in the process. I have highlighted how those mechanisms contributed to the three *sub-niche* developments:

- The activities of *articulation of expectation* can be especially found at the site of the Data Dome and Citizen Sensing, used to attract support. At the Citizen Sensing site, the moralised expectation of the *commons approach of Citizen Sensing* contributed to attracting developers and people with in their home around the project. However, not all *articulations of expectation* processes were successful. In the case of the Data Dome, the *articulation of expectation* suffered in various stages. There were two reasons. One reason is the contradiction between *saying* and *readable action* (e.g. the IP arrangement and the £ 1000 an hour rental fee). People were confused about the messages that innovators sent out and decided not buy-in to the expectation. Another reason is the issue of *interpretation flexibility*. As I have discussed above, sometimes the expectation was too fixed that people could not convert the expectation to their own desires, and sometimes the expectation was too flexible so that it lost the function to guide the direction of innovation.

- The mechanism of *building social networks* happened in all three sites. In all sites, innovators sought to allocate different types of actor networks around the expectations. For example, in the case of the programmable infrastructure, the OPHC engineering team and the OPHC business team aligned technological components suppliers and users (e.g. engineers and big corporations) around the programmable infrastructure. At the Data Dome site, the Data Dome team formed a network around the idea, including technological suppliers, content developers, and a big corporation (H&C). At the Citizen Sensing site, the Citizen Sensing team built a social network around the idea. This included people who have damp issues in their homes, technology developers, and data experts. However, not all social actors were willing to enrol in the project. For example, in the setting of the programmable infrastructure site, there was a lack of involvement of non-engineer researchers, SMEs and ordinary developers. In the case of Data Dome, SMEs and content developers were not willing to develop contents for the Dome.

- The mechanism of *learning,* and especially the *first order learning,* can also be identified across all three sites. *First order learning* is a type of learning that accumulates knowledge to reach a pre-established goal. For example, through observing the interaction between users and the infrastructure, the OPHC engineering team were able to learn more about users' needs and the OPHC business team learnt how to deal with the tricky issue of copyright in the cooperation process. At the Data Dome site, the Data Dome team accumulated a lot of knowledge, such as technology features, suitable contents, and management skills. Very little *second order learning* can be identified in the process. It could have taken place in the Data Dome site, but the negative experiment results did not reach a level that could challenge the original assumptions of the Data Dome.

6.4.2 Vision's paradoxical coordination function

In Chapter 5, I argued that the vision of OPHC was a *prospective structure* which created task divisions and assigned roles for different people and artefacts. It clearly stated what a programmable infrastructure would look like, what a Data Dome would do, how local community organization, Straw House, would help to engage citizens, and what the business agenda of OPHC was to be. In this Chapter, we can see how this *prospective structure* coordinate four different innovation teams (OPHC engineering team, OPHC business team, Data Dome team, and Citizen Sensing team) in the three sites. They all took up the roles that the *prospective structure* assigned to them; built up agendas; and created relevant task divisions to enact those roles.

However, the vision statement of OPHC (*prospective structure*) was insufficient to *coordinate* actions between the different innovation teams. There were no coordinated innovation activities between sites. As we have seen from above, the four innovation teams conducted rather lonely innovation journeys. There were no interactions between them and the lack of interactions created barriers to the realisation of the OPHC vision. For example, the OPHC business team did not coordinate with OPHC engineering team at the programmable infrastructure site. As a result, the OPHC business team continued align users which then created pressure on to OPHC engineering team. At the Data Dome site, the lack of coordination between the OPHC business team and the Data Dome team made the *articulation of expectation* suffer, that is, by *saying* as opposed to *readable action*. At the same site, the lack of coordination between the OPHC engineering team and the Data Dome team made the Dome a dead end and not able to realise the initial vision of use as an urban data visualisation device. At the Citizen Sensing site, the lack of coordination between the OPHC business team and the OPHC engineering team allowed the Citizen Sensing team to proceed with a "wrong" expectation. This "wrong" expectation eventually caused disappointment at Straw House and effected the trust relationship between the OPHC and its local host partners. The lack of coordination between the OPHC engineering team and the Citizen Sensing team also meant that the Citizen Sensing application (Toad) could not use the OPHC's RF Mesh network as they had planned.

Why did the vision statement not provide coordination between the different innovation teams in the different sites? The cause of this *paradox of vision* has historical roots. As we see in Chapter 5 the vision of OPHC was not created in a vacuum by visionaries or prophets. Instead, it was created at the end of a birth process that bundled together various local expectations; there were both pre-existing and new agendas within the vision of OPHC. The actors who took up the roles that the vision of OPHC assigned to them were just doing what they were good at doing and not necessarily thinking of building mutual agendas with each other. As a result, the innovators in each site just focused on their own tasks. For example, the OPHC engineering team constantly modified the HLA according to the latest technologies. They focused on keeping the programmable infrastructure state-of-art rather than thinking about how to work with innovators producing applications for OPHC (e.g. the Data Dome and the Citizen Sensing teams). The Data Dome team came from two institutions: Harbour City Council and the Science Museum. On one hand, they upgraded the dome and this satisfied the need of the Science Museum. On the other hand, they focused on aligning developers to develop content for the dome. This was because one of council's jobs is to create jobs for local innovators. Innovator at the Citizen Sensing site mainly come from Straw House. As a community organisation, its main expertise was to co-produce applications with citizens. So, its priority was to explore the citizen engagement methodology, rather than make sure the application could use the OPHC infrastructure. So, creating an OPHC vision statement which bundled different innovators together did not guarantee innovators in different sites would coordinate with each other naturally. In order to make a system innovation like OPHC work, different innovation teams needed to build mutual agendas with each other. Otherwise, as we have seen, each focused solely on what they were good at and ended up generating different innovation speeds within the system innovation.

It is worth noting that the organisational structure of OPHC did not provide sufficient coordination mechanisms between the innovation teams and sites. OPHC is a joint venture between Harbour City Council and Harbour City University. There were four members on the board panel of OPHC: two from Harbour City University and two from the Harbour City Council. However, there was "*no a belt*" tying the four board members together (Interview with one board member of OPHC, April 2016). Under the board panel, were four managers:

the Chief Technology Designer, the Chief Manager, the Chief accountant, and the Chief Director. However, none of them had the executive power. OPHC believed the magic that linked everyone together, would make things happen naturally. But, unfortunately this was not the case. The reality was that there was no one coordinating the holistic innovation process. In each site, innovation activities were driven by different innovation teams which did not necessarily know each other. It required a system niche actor or system manager to oversee and coordinate the innovation activities between different innovation teams in different sites.

6.4.3 The challenges of citizen engagement

OPHC claims to put citizens at the core of its innovation. The overall goal of the project was to build a programmable platform that would allow an ecosystem of users to use the infrastructure, and it clearly stated that citizens, developers, and SMEs could test their products using the OPHC testbed. Apart from this configuration, it also proposed two citizen related smart city applications. One was OPHC's first application the Data Dome. The application was meant to enable local citizens to interact with their urban data and allow local developers to produce content for the Dome. The other was an opportunity for citizens with less technological know-how to co-create an application with local community organisation Straw House. The empirical data in this chapter captured what happened in reality in those citizen related imaginations.

Engineers and large business were the main user groups of the OPHC infrastructure at the programmable infrastructure site at the time. SMEs and individual developers had a limited role to play in this setting. Although they had a greater degree of know-how skills than ordinary citizens, it was still difficult for them to use OPHC. The gap between SMEs and individual developers and the OPHC testbed could not be solved immediately because it not only involved engineering issues, such as the lack of middleware, but also other issues. For instance, it emerged that SMEs did not have ready-to-test products, and that they have a tendency to work towards the short-term future and cannot afford to conduct experiments.

At the Data Dome site, at the time of this writing, the Data Dome team had not been able to deliver the idea of the Data Dome as an urban data visualisation device. There was no real-time data stream from the city and project onto the dome for people to look at. Even if in the future this imagination was realised. The idea of the Data Dome as a citizen application faces challenges. For example, the dome is not a public place that is free to access and not everyone in the Harbour City can easily come to the Dome to view the data visualisation. Moreover, the Data Dome team realised that letting people see data visualisation of their city would not have a great impact. Meanwhile, for local creative content developers, the original idea is that Data Dome was an opportunity for them to produce creative content. As we have seen the Data Dome team constantly adjusted alignment devices to attract local developers to conduct development for the dome. For example, they used money to encourage developers to make prototypes for the dome. They lowered the entrance barriers for developers to experiment in the Dome. They also built conversion tools for developers to convert their VR/360-degree content into dome content. However, in reality developers were not willing to develop content for the dome. This was partly due to the insufficient *articulation of expectation* that put them off. Another reason, similar to that observed at the programmable infrastructure site, was that developers tend to work toward the short-term future. They preferred to do business that brought immediate benefit, rather than spending time developing content for the Data Dome.

At the Citizen Sensing site, Straw House was regarded as a middle actor between citizens who had few technological know-how skills and the OPHC infrastructure. However, as we have seen there was weak coordination between the Citizen Sensing development and the OPHC infrastructure development. As a result, citizens were not able use the OPHC infrastructure. Although an application, Toad, was generated in this setting, it could connect to the OPHC infrastructure.

In sum, we see that although OPHC scripted many roles for citizens in its vision, in reality, citizens, individual developers, and SMES had limited role to play in the smart city innovation process. The OPHC infrastructure ended up serving the interests of engineers and big corporations.

6.4.4 A failure is not a failure

During the ethnographic research period, none of the three innovations had fulfilled the role that the vision of OPHC had assigned to them in the first place. As we have seen, the programmable infrastructure of OPHC was still not working properly; the RF Mesh network did not open as planned, and there was no a middleware for people to interact with infrastructure, the dome was not able to function as an urban data visualisation device for OPHC, as crucially, it did not connect to the supercomputer. There was also no real-time data collected from the RF Mesh network. And although the Citizen Sensing project produced a concrete outcome (Toad), it was not able to connect it to the OPHC infrastructure.

Nevertheless, these negative innovation results do not immediately make OPHC a failure. This is partly because in early stage innovations, it is often difficult to judge whether an expectation has been met or it is merely a deception. Despite not being able to meet the initial goal, each site generated certain innovation outcomes. For example, the OPHC engineering team set up the physical infrastructure of OPHC and developed some aspects of an HLA for the programmable infrastructure. The Data Dome team configured the physical features for a Data Dome and explored content for the Dome. Straw House co-produced a Citizen Sensing application (Toad) with local communities. These innovation results do not fundamentally go against the scenario that was scripted in the vision of OPHC.

Van Lente (1993) argues that expectation has a dual epistemology. There are two possible directions between the epistemological status of expectation statement and actors' activity. When an expectation is regarded as strong, promising, and workable, actors may prepare to act according to it. In an extreme case (e.g. Moore's Law), they realised the expectation, and the expectation becomes a self-fulfilling prophecy. When an expectation is weak and experimental results are negative, actors might not be prepared to act on it. But, negative experiment results will not immediately effect the certainty of the project. This is because innovators have *interpretation flexibility* about the negative innovation results (Konrad, 2006). *Interpretation flexibility* is the flexibility to interpret the innovation results (See Chapter 4). Innovators can interpret the negative innovation results as problems that can be overcome. Or, as failure this time, but success next time.

So, although none of the three innovations was successful and OPHC was not as open as was intended, innovators can apply *interpretation flexibility* to interpret the innovation results. At the programmable infrastructure site, the OPHC engineering team argued that if they had had more engineers and better communication with the management level, they could have delivered the programmable testbed. At the Data Dome site, although the Data Dome team did notice that the original assumption of the project might be difficult to achieve, this did not make them immediately give up the innovation and kill the project. Instead, they kept trying by adjusting their expectations (e.g. attempting to align VR and 360-degree content producers), creating new agendas and aligning new actors (e.g. commissioning Orbit game to build prototype). Even when the adjusted expectation still hit the wall and the Data Dome remained a dead end, they still not claimed the project to be a failure. The Data Dome team applied *interpretation flexibility* to justify innovation results again. For example, although they did not reach the original goal due to the reason A.B.C..., the project is just weak at the moment but it is still promising if conditions X, Y, Z… are meet. Data Dome has not failed, it is just delayed. At the Citizen Sensing site, Straw House successfully produced an artefact, Toad. They blamed the OPHC for not opening its RF Mesh network in time. The project itself was not a failure. They can still make it work if the RF Mesh network opens.

The experiments at the three sites will continue. As Konrad (2006) points out, as long as the vision of OPHC is still promising, the vision will continue to provide a protected space for future experiments. Innovators will use *interpretation flexibility* to justify current failures. This protection will continue until the expectation collapses. The collapse of the vision will make innovators interpret the same innovation results as negative.

6.5 Conclusion

This chapter has demonstrated the process of implementation of OPHC in Harbour City. Unlike many smart city projects that are implemented in a top-down manner and coordinated by hierarchical organisational structure, the implementation of OPHC was loosely coordinated by a network and a vision of OPHC. It occurred in three parallel *niche* experimentations: the programmable infrastructure, the Data Dome, and the Citizen Sensing. *Around* each *niche*, there was a group of innovators in charge the of experimentation.

Drawing on the conceptual tool, force of vision, we can see that the vision of OPHC provided protection and coordination in the innovation process. However, the coordination function was restricted to coordinate each innovation’s activities and was not be able to provide coordination between sites. Drawing on the conceptual tool of niche internal processes, we can see that innovators in each site spread the expectations, aligned actors around the expectations, configured physical features for the expectations, conducted experiments and learnings about the expectations. In the end, even though each site produced some innovation results, none of them reached goals *scripted* in the vision statement of OPHC. The research also shows that citizens had a limited role in the implementation process of OPHC.

Nevertheless, it is difficult to call the innovation of OPHC a failure. This is partly because it is hard to evaluate what is failure at an early stage of an innovation. It is partly because all the sites produced some innovation outcomes which not-yet against the fundamental vision of the OPHC. It is partly that there is an *interpretation flexibility* to interpret the negative innovation results. And partly because the vision of OPHC provided a protected space for negative experiment results and failures. As long as the vision of OPHC is still promising, it will continue to provide protected spaces for *niche* experiments. So, we can conclude that the implementation process of OPHC is a loosely coordinated parallel niche experimentations with limited citizen participation. Alongside the three parallel innovations in Harbour City, some innovators of OPHC also seek to spread OPHC to the world. In the next chapter, we will look at the phenomenon of diffusion.

"Today I interviewed an actor from Straw House. She expressed disappointment that the OPHC's RF Mesh network is not as open as it promised. She regarded OPHC as a "digital fiction". However, just few days ago, Harbour City was nominated by a Chinese telecommunication company as a smart city leader in the UK, and OPHC is a key reason for OPHC winning award. It is shocking for me to see this contradiction (…)."

Research diary, 30 June 2016

"I am clear about the development direction of the Operating System which is converging everything. The operating system they [OPHC] talk about is actually a network controller system. The name City OS confused me. I thought is it hardware or software? I asked him if it can control or define the sensors. He always talks about Wi-Fi. To be honest, Wi-Fi uses very little in a project. I am not very interested in that (…). I thought they know Li-Fi technology (...). My project in hospitals and prisons are looking for the Li-Fi solution. In a building, there are many individual signals, such as temperature, air conditioning, light, and building management all. The protocol we use now which is hard to define. I thought they (OPHC) could define all the signals. I asked, 'can you define sensors?' But he only talks about the operating system and Wi-Fi (…)."

Interview with a senior engineer in Delta City

Cast III

Vertical Diffusion

Chris, the Chief Manager of OPHC
David, the head of OPHC engineering team.
O3, a research firm in the UK which hired by Flower Action to produce a smart city report.
Peggy, a member of Data Dome team.
Ruby, a civil servant from Harbour City Council.
Susan, the Chief Technology Designer of OPHC.
Vertical Diffusion team, actors (Chris, Ruby, Peggy, David, Susan) spread OPHC to general global smart cities audiences.

Horizontal Diffusion

Actor

Andy, a policy professor from Harbour City University.
Chen Yuan, a Chief Engineer from Delta City Industry and Information Commission (DCIIC).
Director Ma, a civil servant from DCIIC (Delta City).
Green, a staff from Light Speed.
Horizontal Diffusion team, a group of actors (**Chris**, **Green**, **Ruby**) spread OPHC to Delta City.
Lao Zhao, a senior engineer from Delta City.
Li, a Chinese-English translator.
Lulu, a staff from Chinese national supercomputer centre.
Mary, a civil servant from Harbour City Council.
Stein, a co-director of Straw House.
Wan Yan, a civil servant from Delta City Municipal Government.

Companies & institutions

DCIIC, Delta City Industry and Information Commission.
Data exchange company, a big data company in Delta City.
Delta City Health Bureau, a health sector authority in Delta City.
Flower Action, a Chinese multinational networking and telecommunication company.
FCO, Foreign and Commonwealth Office (UK).
Harbour City University, a local university in Harbour City.
Light Speed, a spin-off company of Harbour City University. It provides ‘City OS’ to OPHC.
National supercomputer center, one of national supercomputer centres in China which located in Delta City.
SOFT, a software application research centre in Delta City
Unicorn, a Chinese telecommunication company in Delta City

Around 70 smart cities related companies in Delta City

Cities

Delta City, a city in China and a sister city of Harbour City.
Harbour City, a middle city located in England (UK).
Plateau City, a city in the UK and it is a sister city of Delta city.

Chapter 7

The diffusion process of OPHC

Apart from the implementation of OPHC, another type of activity that I noticed in the innovation process of OPHC is diffusion. This activity happened in a somewhat different from typical models of technology innovation, as diffusion only usually starts when the technology gets to a scalable size and is ready to move. In the case of OPHC, the diffusion happened at the beginning of the innovation and all the way through the process. This chapter aims to investigate this the phenomenon of diffusion. During the ethnographic research period, the diffusion of OPHC was a phenomenon that could be observed in two directions: vertical diffusion and horizontal diffusion. Vertically, OPHC sought to spread its vision to general smart cities audiences. Horizontally, OPHC wants to diffuse the vision of OPHC to audiences in another city.

This chapter starts by investigating the vertical diffusion process (section 7.1). Data for this investigation mainly comes from documents and is supported by some of my participant observation. Drawing on Strategic Niche Management (SNM), it conceptualises the vertical diffusion process as *aggregating* the local smart city niche's (OPHC) experience to the global smart city niche. It applies the *performative role of expectation*, especially the *salient roles* to understand the method of spreading the vision. It then turns to study horizontal diffusion of OPHC through a case Harbour City to Delta City smart city communication (Section 7.2). As a Chinese native, I particularly enjoyed the opportunity to follow this horizontal diffusion process and the empirical data in this section are based on my field observations and interviews.

The end of this chapter (section 7.3), summarises the characteristics of the two diffusion directions. It then applies and develops conceptual tools from SNM and SOE to understand two important themes that emerge in both diffusion directions. It develops the conceptual tool *hype and disappointment cycle* to understand the contradiction between OPHC's increasing global reputation and the local hype. It then adopts Boschma's (2005) four types of *proximity* (*geographical proximity*, *cognitive proximity*, *organisational proximity*, *social proximity*), and my conceptual tool *proximity of expectation* to explain the challenges of diffusing OPHC to Delta City.

7.1 Vertical diffusion

7.1.1 Aggregating OPHC to the global Smart City niche

Since I decided to study OPHC, my first task every morning was to check news updates about OPHC. Because it was impossible for me to follow the key actors of OPHC around the world, online news provided me with a window to access events that I could not attend. Gradually, I noticed that several actors from OPHC (Chris, Ruby, Susan, Peggy, Richard, David) frequently attended smart cities related conferences hosted in Harbour City and beyond (e.g. India, China, Brazil). For example, between March 2015 to October 2016, they attended 'smart cities' events such as the connective cities conference (March 2016, UK), the smart city forum (September 2015, China), the smart city landscape conference (September 2015, India), the innovative cities conference (November 2015, Brazil). They also attended some OPHC infrastructure related technology events. Those technology events focused on technologies that have been used in OPHC, such as 5G technology, broadband, Internet of Things (IoT), wearable technology, and health technology. Why did these key OPHC actors frequently attend smart cities related conferences? What were these conferences for? What did they want to achieve through attending those conferences and events?

Drawing on Strategic Niche Management's (SNM) conceptual tool, the *local niche* and the *global niche*, I conceptualise the activities of attending smart cities related conferences as a way for OPHC to *aggregate* its smart city ideas and experiences to the global smart city niche. According to SNM scholars (Deuten, 2003; Geels and Deuten, 2006), niche development happens at two parallel levels: *local niche* and *global niche*. A *local niche* is where the novelty is based, while a *global niche* is the emerging field of the novel innovations. A *global niche* is often not very stable at the beginning because the "rules of the game" have not yet been formed. *Aggregation* is the process to link a *local niche* and a *global niche*. It is the process of distilling valuable local lessons from *local niches* to a *global niche* (See more in Chapter 4). Gradually, rules at the *global niche* level will be formed and the *global niche* will become more and more stable.

So, if we regard OPHC as a local smart city niche, then the smart cities related conferences it attended could be regarded as *aggregation infrastructure* that enables local smart cities niches such as OPHC to *aggregate* their experience to the global smart city niche. The global smart city niche indicates an emerging smart city field. At the moment, the field is still at a stage of formation without unified definitions and standards about what a smart city is. I illustrate the interactions between the local smart city niche (OPHC) and the emerging global smart city niche in **Figure 38** below. From the direction of diffusion, I call it vertical diffusion. As we can see OPHC smart city is at a local niche level. Innovators of OPHC *aggregate* OPHC to the general global smart city niche. The global smart city niche is still not stable at this time. So, I use dotted-line in the figure to indicate its emerging and stabilisation process. It is worth noting, according to SNM, apart from the innovators of a project, (*systemic*) *intermediary actors*[41] are another group of people who aggregate local smart city lessons to the global smart city niche. In this ethnographic research, I have identified five (*systemic*) *intermediary actors* that have contributed to *aggregating* OPHC to the global smart city niche. They are standard organisations, UK government agencies, community organisations, industry associations, and research institutions. However, due to the limitations on data collection, I have not been able to follow their *aggregation* activities in detail. So, in this section, I mainly focus on OPHC innovators' *aggregation* activities. If readers are interested in finding out more about the *intermediaries/system intermediaries*, please see appendix 8 (4).

[41] They are called intermediary actors because they act between a local niche and a global niche. They are actors who monitor multiple local projects and help circulate local knowledge (Schot and Geels, 2008). "System intermediary actors" means intermediary actors working at a network level according to Van Lente et al. (2003). See more in Chapter 4.

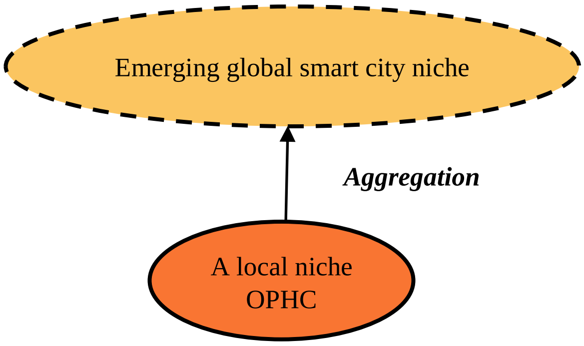


Figure 38. *Aggregating experience of OPHC to the emerging global smart city niche*

7.1.2 Inflating the vision of OPHC to attract attention

OPHC was still at the vision stage, so articulating the vision of OPHC was the main way for OPHC innovators to *aggregate* OPHC to the global smart city niche. The vision statement of OPHC contains key messages that OPHC wants the global smart cities audiences to listen to, including messages about its programmable infrastructure, citizen participation, and embracing of 'Fun City'. Chris was the main person to travel around the world to talk about OPHC. Occasionally Ruby, Susan and other OPHC actors took up this spokespersons' role. I call them the vertical diffusion team. Although they came from different backgrounds, the way they talked about the vision of OPHC was very similar. For example, they all talked about elements such as "*why was OPHC built?*", "*What is the infrastructure of OPHC?*", "*Who are the potential users of OPHC?*", "*What OPHC aims to achieve?*" In their speeches, they often used the examples of the Data Dome, Straw House's Citizen Sensing and DOCK' 'Fun City' initiative to demonstrate possible use case of OPHC and its citizen engagement considerations. As we saw in Chapter 6 the Data Dome remained at the experimental stage. Citizen Sensing and 'Fun City' initiatives were also not using OPHC infrastructure at all. Van Lente (1993) noting this phenomenon pointed out that in the early stage of an innovation, the vision is often inflated in order to attract attention. So, the vertical diffusion team talking about those 'not-yet' realised examples as if they were real was a strategy to help OPHC attract attention.

Moreover, there was another rhetorical skill that was used to inflate the vision, that of the pervasive use of the word "*first*" in their speeches. There were different types of "*first*" scripted in the discourse of OPHC and I select several examples below. They are extracts from the spokesmen' presentations, public speeches, and slides.

"We have the first open NFV test-bed. It is the first time that we propose to use SDN and NFV in a smart city."

Presentation at an SDN Workshop, March 2015

"We are building the world's first open programmable city. A ground-breaking project aimed at providing a platform for the development of applications that will promote innovation and better quality of life."

Harbour City News, 5th March 2015

"The revamped 100 seat planetarium will feature two 4K resolution projectors powered by 17 computers to deliver a 120Hz 3D model of the universe. It is claimed that this will convert the facility into the UK's first 3D planetarium."

Local News, 10th October 2015

"We are creating a 5G test-bed in Harbour City; we are probably one of the first places in the UK and Europe."

Fieldnotes, presentation at an IoT event, May 2015

From the quotations above, we can see many "*firsts*" have been used in OPHC discourse. For example, "*the first SDN and NFV smart city*", "*the world's first open programmable city*", "*the UK's first 3D Planetarium and Data Dome*", "*the first 5G test-bed in the UK and Europe*". Why were so many "*firsts*" used in communicating the vision of OPHC? In order to understand the role of "first" in communicating OPHC, I draw on conceptual tools of vision's *salient role*. Van Lente and Rip (1998) argue that expectation is performative in nature. Expectations are not merely descriptive, but also do something. One of its function is to help to raise attention and attract resources (see more in Chapter 4). When *articulating the expectation*, Van Lente (1993) finds that a vision often has a *salient role* to play at an early stage of innovation because at this stage promising technologies do not have unified standards and regulations. Relevant innovators from different places tend to compete with each other to get to the salient point for others to look at. This is especially true of technological and scientific innovations. Randall Collins (1975) vividly captured how scientists seek to become salient. He regards science as an open plain. Scientists are actors who stand on the plain and shout "*Listen to me! Listen to me!*" As Van Lente (1993: 224) quotes Collins (1975: 480), "*the struggle for salience is not limited to technology. It has its analogue in science, where scientist hopes to find others joining their direction*".

To further understand how vision's *salient role* operates, we need to briefly revisit its origin from game theory, the 'coordination game'. Back in the 1960s, Thomas Schelling conducted a famous experiment. He asked people to meet one another in New York City without communicating with each other. Despite many possible meeting locations, a majority of participants choose Grand Central Station as a meeting place. This is because at that time, the Grand Central Station was the most salient traffic hub in New York. The case helped Thomas Schelling to generate the idea of the 'coordination game'. Simply speaking, the 'coordination game' means in a situation where people do not know where to go, they will do "A" because they think others will do "A". They will do "B" because they think all people will do "B". Inspired by the concept of the 'coordination game', Van Lente (1993) argues that innovators sometimes seek to make their vision like Grand Central Station, that is, the tallest, most visible, and most salient place. A place that people will go when they do not know the meeting place. In order to become a salient point, a vision of promising technology is often inflated by actors. By doing this, they aim to establish a salient role for others to look at and follow (Berkhout, 2006). Van Lente (1993) uses an example of a parachutist to describe vision's *salient role*. He asks, when a group of parachutists meet in strong wind and cannot spot each other, how will an individual parachutist make choices when the choices of others are unknown to him? They might guess what others will do. The most likely answer in Van Lente's example is the church tower: the highest point that is visible to everyone. The highest point is a place where everybody is likely to go. So, each parachutist might reasonably expect the others to go the church tower.

After knowing how the *salient role* operates, we can see how the rhetoric of "first" used in OPHC discourse was seeking to help OPHC establish a salient position in today's smart cities movement. In current worldwide smart cities making, there is no a standard way of constructing smart cities. Each city and their actors propose their own smart city solutions. Many smart city players show ambitions of becoming leaders in this movement and the OPHC project is not an exception. In order to attract attention, resources, alliances and support, the rhetoric of "*first*" was used to help OPHC establish a *salient role* for others to look at and follow.

7.1.3 The contradiction between high rising global reputation and increasing local disappointment

The inflated vision of OPHC helped OPHC attracted a lot of attention from audiences at the level of the global smart cities niche. OPHC's global reputation was largely enhanced as the result of *aggregation* activities. At the time of writing (February 2017), the search engine, google, brought up 75,700 items about the project. Ruby described the OPHC's change from invisible to visible,

> *"for a long time, we kept things below the radar. In order to get things off the ground, it is a space to be. When you above the radar, you are very visible. Everybody looks at what you do. It is hard to be creative and take a risk (...). We are very visible now. Everybody is looking at us and at what we are doing (...)."*
>
> *Interview with Ruby, April 2016*

As evidence that the vision of OPHC was acknowledged by the global smart city niche, actors at the global smart city niche gave OPHC two prestigious smart cities awards. In summer 2016, Digital Forum[42] gave OPHC a smart city innovator award because OPHC had demonstrated a positive impact on "*the lives of citizens*", "*the cost of delivering services within a city*", and "*the applicability of the innovation to other cities around the world*" (Digital Forum, May 2016). A week after OPHC received the smart city innovator award, it received another a UK smart city leader award from the Chinese telecommunications company Flower Action. The award was based on the research of O3[43], and it suggested that OPHC had shown distinctive thinking in the area of "*open data accessibility*", "*energy innovation*", and "*community engagement*" (Official report of O3, May 2016). Looking at the reasons that OPHC won both awards, we can see that the elements embedded in the vision of OPHC, such as the programmable infrastructure, 'Fun City', and citizen engagement were elements that OPHC contributed to the global smart cities niche. They brought new thinking and aspirations to the global smart cities niche. They have been inspirational because they have shown a smart city making approach which is different from the corporate-driven smart city vision or the surveillance idea of smart cities. Gradually, the

[42] Digital Forum is an industry association intermediary actor. It hosts global scale smart cities conferences to attract smart city actors around the world to participate and share their experiences.

[43] O3 is an intermediary actor hired by other firms to compare smart cities experiences in different locations and draw some general conclusions. It produces a UK smart city index and it regards OPHC as a UK smart city leader.

increasing reputation and the awards OPHC has won has helped it establish a leading position in the current ‘smart cities’ movement. One board member of OPHC reflected this leading position in interview,

> *“There is a real value to be seen as a world leading in the area. The Chief Technology Designer is clearly a world leading academic. Clearly, lots of people think what we are doing here in the Harbour City is a cutting edge. There was a real value for Harbour City as a city to been known worldwide (...).”*
>
> *Interview with a board member of OPHC, 19 May 2016*

An interesting phenomenon happened when OPHC won the two prestigious awards at the global level; the OPHC host partners in Harbour City experienced huge disappointment. The quotation at the beginning of this chapter expresses this disappointment. Local host partner’ projects were adopted as examples when introducing the vision of OPHC. For example, the citizen engagement and ‘Fun City’ elements were *scribed* in the vision of OPHC which contributed to raising OPHC’s global recognition. They were also the valuable lessons that OPHC contributed to the global smart cities niche. However, in reality none of local host partners were actually using OPHC. As we have seen in Chapter 6, Straw House bought-into the vision of OPHC, adopted the role of facilitating citizen engagement in OPHC, and co-produced an application (Toad) with citizens. Straw House had the huge expectation that they could hang the Toad on OPHC’s RF Mesh network which according to the OPHC business agenda would be available soon. As a member of Citizen Sensing team stressed, “*they talk as if the infrastructure [OPHC infrastructure] is there and waiting for people to use it*” (Interview with a member of Citizen Sensing team, 30 June 2016). But, in reality the planned launch date of the RF Mesh network was postponed again and again and in the end citizen co-created application Toad was not able to use the OPHC RF Mesh network. This generated disappointment at Straw House. The inability to connect to the OPHC infrastructure was also true for other local partners, such as the DOCK. The ‘Fun City’ initiative generated by DOCK was considered as a possible application for OPHC and highlighted in many OPHC speeches. However, DOCK only received several packets from OPHC (Interview with the Director of DOCK, May 2016). Thus, OPHC winning two awards at the international level, was criticized at the local level where it was felt that OPHC’s promises were in fact empty promises. This also damaged the trust relationship between OPHC and local partners. A board member of OPHC reflected the trust crisis in the interview:

> *"OPHC is getting criticized about not actually delivering any of those experiments. And, certain partners are criticising us (...). People said that there were lots of promises, but we are not engaging and developing those ideas (...)."*
>
> *Interview a board member of OPHC, 9 May 2016*

In order to change the situation, I heard that local host partners (e.g. DOCK, Straw House, BOX, and Science Museum) had got together and established a partnership board in autumn 2016. The partnership board's aim was to strengthen the relationship between the local partners and OPHC, and to make OPHC actually work for local host partners (Interview with Rufus, 15 August 2016).

7.2 Horizontal diffusion

7.2.1 Diffusing OPHC to another local niche

Alongside OPHC's diffusion (*aggregation*) to the global smart city niche, the vision of OPHC also sought to diffuse to another local smart city niche, Delta City (China). If we regard diffusing OPHC to general global smart cities audiences as an *aggregation* process between the local smart city niche and the global smart city niche, diffusing OPHC to Delta City can be regarded as diffusing OPHC to another local smart city niche. I show the diffusion direction in **Figure 39**, and call it horizontal diffusion because of the direction of diffusion. Below, I guide you through the story of the diffusion process.

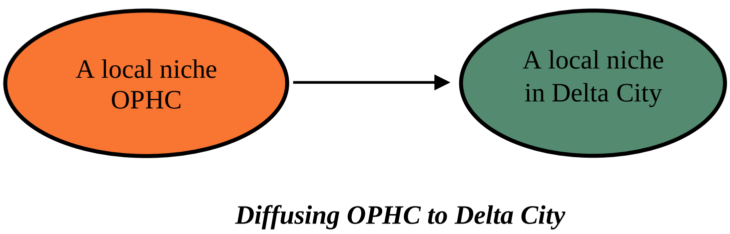


Figure 39. *Diffusing OPHC to Delta City*

As with the diffusion of OPHC to general global smart cities audiences, articulating the vision of OPHC has been the main way of diffusing OPHC to Delta City. However, the diffusion of OPHC to another *local niche* is not vertical *aggregation*, rather horizontal development. So, I turn to the spatial niche development literature (Coenen et al., 2010). As it is about diffusing a smart city project from one city to another, Boschma's (2005) concept of *proximity* is useful. Coenen et al. (2010) incorporate Boschma's (2005) five *proximities* into the concept of niche to understand the spatial dimension of niche development (See Chapter 4). In this research, I have adopted Boschma's (2005) conceptual tools *proximity* to understand the diffusion process. I specifically focus on four types of *proximity* that they were identified in the iterative data collection and analysis process. *Geographic proximity* (the geographic distance between actors). *Cognitive proximity* (shared knowledge background that enables communication, understanding, absorbtion, and successfully processing new information). *Social proximity* (social relations between agents at a micro-level based on friendship, kinship and experience). *Organisational proximity* (a set of interdependencies within and between organisations). Moreover, diffusing OPHC to another foreign place involved elements that Boschma's (2005) *proximity* model did not cover, namely, the expectation of technology in another culture context. Drawing on Van Lente's (1993) levels of expectation (*macro-*, *meso-*, *micro-*), therefore I further develop Boschma's concept and argue that the *proximity of expectation* is another element that influences spatial niche development.

7.2.2 The background of the case

Before going into detail about the diffusion process, it is necessary to revisit some background information about the case. For example, what did OPHC want to diffuse? Why Delta City? and what diffusing infrastructure or channel is there? In the vision statement of OPHC, we can see that it imagined other cities around world could use the OPHC infrastructure to test their smart cities applications. Two quotations from OPHC vision statements reveal this ambition:

> *"Cities like Delta City (China) or New York will be able to effectively simulate their own network traffic on the Harbour City's network. This means engineers in Harbour City can help international authorities to predict the capacity they will need to connect their metropolis."*
>
> *Harbour City Post, March 2015*

> *"We said to Delta City, 'let's make the network look like Delta City one day. You can come here (refers to Harbour City) and play around with things that are happing in Delta City. Using us (OPHC) as a testbed for Delta City'. They liked that (...)."*
>
> *Chris speak at a public event, May 2015*

The technology enabler behind this idea is the 'Network Emulator' explained in Chapter 5. Simply speaking, it is a piece of software developed by NEXT Lab that can replicate real physical nodes in Harbour City and simulate as many virtual nodes as needed in a virtual world. Through those virtual nodes, other cities can configure whatever network typologies they want through the 'Network Emulator' and test their products in a simulated environment from a distance (Harbour City Post, 11 March 2015). Neither quotation uses the Chinese city, Delta City, by chance. In 2016, Delta City and Harbour City had been sister cities for fifteen years. In 2012, the mayors of both cities signed a memorandum on Sustainable Urbanisation in Beijing (China) and a specific agreement was assigned to smart cities (Fieldnotes, 11 July 2015). Under the memorandum, the two cities started to have conversations around smart city development. In 2015, Chen Yuan, a Chief Engineer from the Delta City Industry and Information Commission (DCIIC), visited Harbour City. He heard about the OPHC project during his visit and was impressed by OPHC's holistic approach. He expressed the potential for Delta City to learn and partner with OPHC. Since then, Chen Yuan's comments had been interpreted by OPHC as "*Delta City is an emerging partner of OPHC*" (Harbour City Council News, 10 March 2015) and this is why Delta City was used as an example in the above quotations.

The possibility of diffusing OPHC to Delta City was explored through a new linkage called the *EU-China Harbour City-to-Delta City smart city programme*. It was a one-year program funded by the Foreign and Commonwealth Office (FCO) in the UK. The programme aimed to facilitate smart city interactions between the two cities and explores the collaboration possibilities (Fieldnotes, 11 July 2015). The programme was led by Mary who joined Harbour City Council in 2014 and had language skills in Chinese and rich work experience in the Chinese foreign office. In collaborating with her former colleagues in the Delta City British Consulate, she quickly found a key official partner on the Delta City side, the Delta City Industry and Information Commission (DCIIC). DCIIC is a Municipal government body in Delta City and it is a branch organisation of the Ministry of Industry and Information

Technology (MIIT)[44]. As its name indicates, DCIIC is in charge of Delta City's industry and information technology development. Compared with other smart cities authorities in Delta City, DCIIC shares more similarities with OPHC, because they both focus on network infrastructure and care about the use of data in smart cities.

If we say conferences are a diffusion infrastructure between OPHC and the global smart city niche, then the, EU-China smart city Programme is a diffusion infrastructure for OPHC to spread its vision to Delta City. Mary took responsibility for designing the programme agenda. Because two cities have a thousand miles geographic distance, delegations visiting was considered as one option to reduce the physical distance barriers. However, Mary heard from her Chinese colleagues that a new regulation released by the Chinese government that meant Chinese official overseas visits could only last no more than five days (Fieldnotes, 11 July 2015). In the end, Mary decided to have a series of three webinars to help both parties to narrow down their mutual interests and have a delegation visiting from Harbour City to Delta City at the end (Fieldnotes, 17 March 2016). Mary had heard my name from several people in Harbour City, and given that I am a Chinese student studying Harbour City's smart city, Mary very quickly contacted me and welcomed me to observe the whole programme. My focus was to explore how OPHC diffused to Delta City. Not all the activities of the programme were related to this research focus. For clarity, I illustrate the key events in the programme and highlighted the OPHC relevant episodes (two webinars and the delegation visiting (Day 1, Day 2, and Day 5) in **Figure 40**.

[44] In general, there are around eight ministry levels of smart city actors in China. MIIT focuses on integrating technologies in the urban infrastructure and upgrading local industries. MIIT's approach to smart city is different from the other seven smart city authorities. Taking the Ministry of Housing for example, which focuses on exploring how the idea of the smart city can help solve the housing issue in an increasing crowded city.

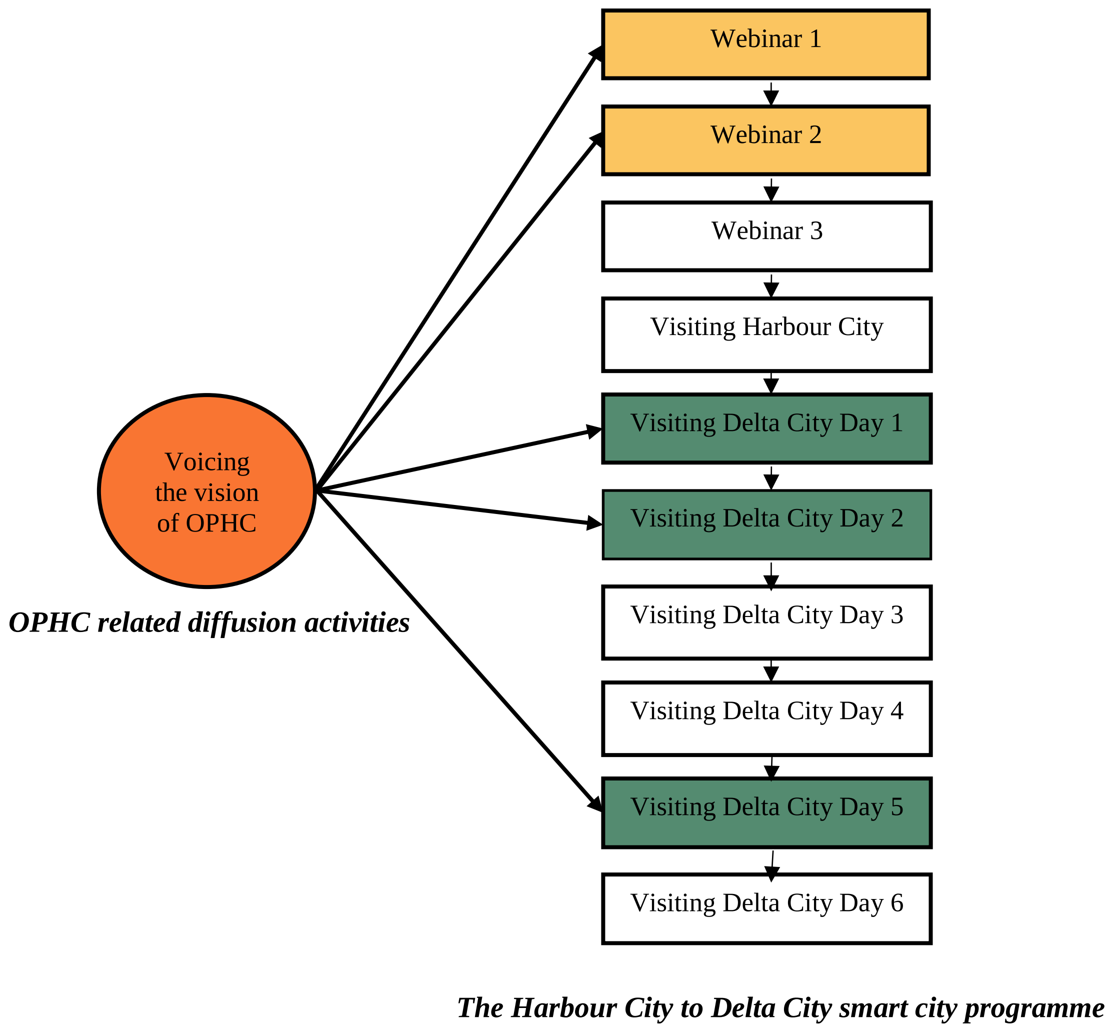


Figure 40. *Events in relation to diffusing OPHC*

7.2.3 Diffusing OPHC to Delta City

(1) Webinar 1: Encountering DCIIC's Smart City niche

The first webinar was hosted in July 2015. It was early morning in Harbour City but it was the last meeting for Delta City colleagues before going home for dinner. The aim of this webinar was to get to know each other's vision, organisational structure and social networking. Participants on the Harbour City side included Mary, two civil servants (Ruby, Richard), the Chief Manager of OPHC (Chris), a-co-director of Straw House (Stein), and a policy professor from Harbour City University (Andy). They sat around a table in a room at DOCK with a huge TV screen in front of them. Using a digital conferencing system, colleagues in Delta City appeared on the screen, including Director Ma from DCIIC and several of his colleagues, Lulu from the Chinese National Supercomputer Centre, and a translator Li.

Ruby was responsible for introducing a wide range of smart cities components in Harbour City, including, energy, transportation, and the smart city infrastructure. OPHC was briefly mentioned as a flagship smart city project in the Harbour City. After Ruby's introduction, Director Ma from DCIIC talked about DCIIC's smart city niche. DCIIC's smart city project was initiated top-down by local authorities. The key official document behind it is called *Implementation of Constructing Delta City's Smart City (2012)*. DCIIC as an authority in the technology sector took responsibility for leading a smart city project. Like OPHC, DCIIC's smart city project also seeks to respond to the increasing urban population. But unlike OPHC treating the smart city as a marketing opportunity, DCIIC's smart city project regards the smart city as a way to "*intensify core competitiveness*" (Fieldnotes, July 2015). DCIIC also has its own smart city vision. Director Ma used a tree structure to explain this vision: the information infrastructure (e.g. a supercomputer, networks, and mobile base stations) are regarded as the roots of a tree. The core technology and intelligent industries (e.g. e-commerce) are the trunk of the tree and the branches. Smart city applications are considered as the leaves of the tree, such as an e-government application "*online administrative Hall*", a public service application "*Future Hospital*", and a city management application "*intelligent transport*". Like OPHC, the smart city niche in Delta City has also aligned a network of actors around it, including the Delta City Health Bureau, Data exchange company, a software application centre SOFT, smart city innovation research centre, national supercomputer centre, and many smart cities related companies. After both sides had spoken about their visions, there was about 30 minutes question and answer time. Participants on Harbour City side were keen to understand DCIIC's role in Delta City, because they wanted to make sure that they contacted the right people. While the Delta City team, they asked questions relating to their concerns of building a smart city, such as data privacy, robotic labs, and incubators.

It is difficult to draw conclusions about the Delta City actors' thoughts about OPHC at this stage. But based on my observations of the interactions, there were two factors that affected the articulation of the vision of OPHC to DCIIC colleagues. First of all, the Delta City officials did not share a similar knowledge background with OPHC. Boschma (2005) calls this knowledge gap in communication *cognitive proximity*. For example, as I observed in the meeting, no one on the Delta City side picked up the most innovative aspect of OPHC, that is, the city-scale interconnected programmable testbed. In order to pick up this idea, Delta City colleagues would need to share the knowledge background of Software Defined Network (SDN). Although some participants on the Delta City side have engineering backgrounds (Director Ma and some colleagues from national supercomputer centre), they are not experts in the area of high performance networks, so they did not pick up on the network innovation of OPHC. Another factor is that officials on Delta City side had their own preference of technologies. I observed in the webinar that they were excited when Harbour City mentioned certain technologies (e.g. robotics). This unusual excitement reflected a cultural expectation of technology which I will unpack later.

(2) Webinar 2: The Challenges of Articulating the Vision of OPHC to Delta City Officials

Another webinar was hosted in August 2015. This webinar specially targeted digital infrastructure. This provided OPHC with a stage to spread its vision to DCIIC officials. Ruby, Richard, Mary, and Chris sat in the same room in the BOX. The meeting did not start as planned because the digital conferencing system met some connection problems. They were quite jolly and thought the bad connection was a sign of poorer network capacity in Delta City. For a city with a population of 16 million, it must difficult to manage their network in peak hours. So, they might need OPHC's network solution. It took a while for Delta City colleagues to appear on the screen. They were some familiar faces, such as Director Ma, his colleagues, and translator Li. There were also some new faces, such as staff from a local software application centre SOFT and the national supercomputer centre.

After the greeting, Chris was given 15 minutes to talk about the vision of OPHC. As usual, he began with introducing the components of the programmable testbed (e.g. optical fibre rings, Wi-Fi network, and RF Mesh network, etc.). This was followed by an introduction of the ecosystem of users. Then, he introduced two use cases: a sensor-enabled care-house and using IP cameras to capture nature. Both cases were news to me because I had not heard that OPHC had any real applications yet. Chris finished the speech by emphasising the promising SDN solution. However, Chris's speech not as effective as it could have been. One reason was technology noise. The unstable webinar network connection caused a delay in the presentation slides. So, what appeared on the webinar screen was not synchronised with what

Chris was saying (Fieldnotes, 08 July 2015). Audiences in Delta City side had difficulty following Chris's presentation. Second, there was a lack of *cognitive proximity* between Chris and the translator Li. Communication between two languages requires a translator. The translator Li functioned as a mediator who delivered messages from one side to another. Since translator Li did not understand the technological aspects of OPHC, she had difficulties translating the technical terms of OPHC. As translator Li explicitly confessed in the webinar she felt the technological components were too complex to translate. So, she skipped all technological related elements and merely talked about two use cases (Fieldnotes, 08 July 2015). As a result, a large amount of the technological aspect of OPHC was lost in translation.

On the Delta City side, a young engineer from SOFT introduced a smart city application that they are very proud of. It was an international award-winning smart street lighting solution. Despite the bad network connections and the strange English accent, participants in Harbour City grasped some of the ideas about the smart street lighting solution. It is an application that people can use on their smart phone to adjust street lighting and SOFT calls this system an operating system (OS) as well. The choice of this application is very interesting because they did not talk about "*Future Hospital*" or "*intelligent transport*" that they had emphasised in the previous webinar. The informal chat with Director Ma later revealed more about this choice. He had heard that there were many lampposts in the OPHC project and he thought it might be possible to sell SOFT's smart street lighting system back to OPHC (Informal chat with Director Ma, March 2016). However, this choice reflected their misinterpretation of OPHC. Although OPHC has "*lampposts*" and "OS" in its project, both terms have different connections. The lampposts in OPHC are not merely to provide smart lighting. Moreover, they host the OPHC's RF Mesh network. While the word "OS" in the context of OPHC means a network operating system that enables the reconfiguration of heterogeneous networks (e.g. fibre network, wireless network, and RF Mesh network). While the "OS" in SOFT's idea is a system that coordinates Internet of Things devices (e.g. sensors). In other words, SOFT's "OS" could be thought of as part of OPHC's RF Mesh network concept. The different understanding of the use of lampposts and "OS" in smart cities made articulating the vision of OPHC difficult, because the DCIIC perception of OPHC was mistaken.

(3) Visiting Delta City-Day1

Six months later, on an early morning in March 2016, a flight arrived in Delta City airport. I was allowed to follow the delegation visiting Delta City. In return, as a native Chinese speaker, I agreed to provide some assistance to the delegation (translation). I arrived in China a week before the delegation visited and I took the chance to go home and fly to Delta City a night before the delegation visit. As part of my assistance job, I helped to pick up delegates at Delta City airport. It was the first time in my life I had picked up someone at an airport! Seeing the flight arrive at the airport reminded me of Serres's observation,

> "*Aircraft carry letters, telephones, agents, representatives and the like: we use the term communication to cover air transport as well as post. When people, aircraft and electronic signals are transmitted through the air, they are all effectively messages and messengers.*"
>
> *Serres, 1995: 8*

The plane landing in Delta City airport is like an angel of steel that carries angels of flesh and blood: Harbour City delegates. They have messages about smart cities to send to Delta City audiences. Amongst the delegates, there were two OPHC related delegates: Chris (The Chief Manager of OPHC) and Green (a representative from OPHC's 'City OS' provider Light Speed[45]). Chris took responsibility for articulating the vision of OPHC, while Green specifically focused on promoting the SDN controller.

Despite the jet-lag, the delegates started to meet people that afternoon. They were divided into two groups: the business group visited a local telecommunications company called Unicorn, while the delegates from the City Council and University went to visit the Delta City Municipal government. Chris and Green joined the business group and visited the Unicorn. The visit to Unicorn was meaningful because the company is one of three main telecommunication companies in China and it understands SDN. I was assisting with the Municipal government visit, so I did not see how Chris and Green promoted OPHC's SDN solution. However, the interview afterwards showed that diffusing OPHC's solution to Unicorn suffered because Unicorn already had its own vision of developing SDN and an SDN controller (Interview with the head engineer of OPHC, August 2016).

[45] The City OS was initially developed by the NEXT Lab. Then, it created a spin-off company calls Light-Speed to promote the 'City OS' solution.

Meanwhile, I followed another delegation group to the Delta City Municipal government. They were surprised to find out that Delta City has 31 sister cities around the world and Harbour City is just one of them. Moreover, Harbour City's neighbour, Plateau City has a strong connection with Delta City. Although their friendship had been slightly shorter than Harbour City's friendship with Delta City, Plateau City, had already gained Delta City's trust and the friendship had already brought research funding to Plateau City. In the evening, the delegation had dinner with people from the Municipal government. At the dinner table, Wan Yan, a civil servant from the Municipal government, asked me about OPHC. She said that she had no idea about what OPHC is and was not sure about the feasibility of the project. She also explained why Delta City trusted Plateau City; every year the same vice-chancellor of the University of Plateau would visit Delta City and each time he would bring research projects for Delta City to collaborate with. Their long-term commitment meant Delta City Municipal government trusted them and were willing to give them research funds (Research Diary, 17 March 2016). Plateau City's success reflects Boschma's (2005) argument about *social proximity*. *Social proximity* means social relations at a micro-level that are based on friendship, kinship, and experience. Boschma (2005) suggests that if there is too little *social proximity* it will be difficult for both parties to communicate with each other and exchange tactical knowledge because trust between actors is required before they can commit their resources and knowledge (Coenen et al., 2010). Clearly, Plateau City had developed close *social proximity* with Delta City and won their trust through the past 15 years' commitment.

(4) Visiting Delta City-Day2 (Morning)

The next morning, delegates had a very nice southern China buffet breakfast in the Hotel. It was going to be a long day. In the morning, they would be attending a smart city conference hosted in the hotel and in the afternoon, they would have one-to-one business meetings with local companies. I met Green in the elevator and he told me that it was going to be a super busy day for him because he would be meeting 15 companies in the afternoon.

The conference started at 9am. The audiences included the DCIIC and representatives from 70 smart cities companies. After Ruby talked about smart cities projects in Harbour City, Chris was given 15 minutes to talk about OPHC. Before his speech, he played a video clip about OPHC to provide background information for people who are not familiar with Harbour City and OPHC. The video talked about the world's rapid urbanisation, the idea of the programmable city, the promising technology Software Defined Network (SDN), the importance of data and citizens in a smart city project. The visual images companies with sci-fi genera background music which helped to create a futuristic atmosphere. After playing the video, Chris introduced the OPHC vision. As on other occasions, the vision of OPHC was inflated in order to attract attention. For example, he talked about the 'not-yet' realized, project as if it was realized and he incorporated the rhetoric of "*first*" to help OPHC establish a *salient role* in the current smart cities movement (Fieldnotes, 18 March 2016). In order to understand the audience's response to OPHC, I interviewed some of the participants during the tea break. The interviews show that there was no *cognitive proximity* between participants and OPHC. They had attended the meeting to search for components that could fulfil their own individual expectations. For example, some of the attendees came from a local bus company who wanted to learn more about smart transport management. Others were venture capitalists who want to find promising SMEs to invest in. Some were technological incubator companies who wanted to learn from successful incubators. Some had come from international Intellectual Property service companies wanting to become mediators in the global smart city business, so on. The lack of *cognitive proximity* made it difficult for them to understand the revolutionary vision that Chris described. Their private expectations were guiding them to look for specific technology, rather than to understand the vision of OPHC.

On Delta City side, Director Ma introduced DCIIC's smart city vision. As in webinar 1, he referred to many grand visions from the national and the municipal level before introducing DCIIC's smart city vision. I present an extract of his speech below:

> *"2016 is the first year of the 13th Five-year plan. The state is further implementing strategies such as the Silk Road Economic Belt and the 21st-Century Maritime Silk Road[46], free trade zone[47], Made in China 2025[48], National big data strategy[49]. They all bring huge economic benefits for Delta City. Within the 13th Five-year plan period, Delta city proposed several strategic visions. It suggested further accelerating industrial upgrading, and building a national shipping and logistic centre and modern financial service system, and building a national urban innovation centre …"*
>
> *Director Ma presentation at smart conference, March 2016*

[46] A strategy to facilitate the exportation of Chinese products.
[47] A testing ground for some economic and social reforms.
[48] A technology related macro agenda which focuses on upgrading its industry through intelligent manufacturing.
[49] It is a technology related policy which emphasises the importance of data.

The action of referring to the many grand visions before talking about DCIIC's vision shows that two factors affected DCIIC's decision making in developing its smart city and its potential buy in to the vision of OPHC. The first factor is that DCIIC is embedded in a hierarchical structure. Vertically, it has to follow the instruction of national government, such as the Ministry of Industry and Information Technology (MIIT). Horizontally, DCIIC has to coordinate with other government bodies in Delta City. From this point of view, DCIIC has high *organisational proximity* because it has high interdependency within and between organisations. This is why when it communicates its vision, it often refers to the official documents from the Municipal government and national strategies to show that DCIIC is line with them. Seen from this angle, we can see that DCIIC as a local authority has limited agency to design its smart city, I will expand on this point later in discussion section.

Apart from the high *organisational proximity*, the multiple-level of expectations in the Chinese context is another factor affecting DCIIC's decision making. As we see in the quotation above, Director Ma mentioned a series of national and municipal strategies, such as "*the Silk Road Economic Belt and the 21st-Century Maritime Silk Road (B&R)*", "*free trade zone (FTZ)*", "*Made in China 2025*", "*National big data strategy*". All these are *macro agendas* at levels of Chinese society reflecting China's concerns at the moment. Rapid industrialisation and marketisation have brought China an economic boost in past 40 years, especially in the Delta City region. However, the labour-intensive factories cannot sustain future growth. So, upgrading the existing industry is considered as a way to break though the bottleneck of growth, while the experiment of the "*free trade zone*" and building the "*silk road economic belt*" are ways to enhance the economic connections with other countries to benefit the export of Chinese products. Taking this background into consideration, we find the emphasis of the smart city in todays' Chinese urbanisation naturally converges with the idea of upgrading industry because they both emphasise the importance of technology. From this, we can see that different cultures have different macro expectations at different historical times. Particular technologies that are prominent in certain cultures reflect not just global trends but also connections with the culture's deepest hopes and fears. These macro expectations in Chinese society affect expectations at the meso- and micro level (Van Lente, 1993). For example, Delta City municipal has generated a series of strategies which follow the national government's macro agenda, such as "*accelerating industrial upgrading*", "*building a national shipping and logistic centre*", "*building a modern financial services* *system*", "*building a national urban innovation centre*". Both the macro level expectation and meso level expectations influenced the DCIIC's smart city vision at the micro level. Situated in this social-cultural context, DCIIC officials inevitably paid attention to certain technologies than other. For instance, in the first webinar, DCIIC paid more attention to the robotic technology which fitted into their macro expectation of upgrading industry.

(5) Visiting Delta City-Day 2 (Afternoon)

In the afternoon, companies had a chance to have one-to-one meetings with Harbour City's companies. Many companies signed up to meet Chris and Green. In order to understand their reactions to OPHC and the SDN controller, I had a series of informal interviews with participants after they had met Chris and Green. The interview results show that it was difficult for companies to buy into the vision of OPHC due to two reasons: *cognitive proximity* and people' private expectation. The interviews evidenced that most companies did not share a similar knowledge background with OPHC. The cognitive distance between the audiences and the SDN solution made it difficult for companies to relate their business to OPHC. Of more interest in the interviews was that although some actors shared some knowledge about the network, they still do not want to buy into the vision of OPHC. A Chinese multinational networking and telecommunications company called Flower Action provides a good example. Flower Action is dedicated to developing a Software Defined Network and Network convergence in China, so the company shares a similar network vision with OPHC. A Representative from Flower Action talked to OPHC and its SDN provider Light Speed. The close *cognitive proximity* between the two parties did not however immediately facilitate communication; because SDN is an emerging field without unified standards and much in the way of Intellectual Property (IP) protection, and so both parties were conservative about going into detail about their technological features. As one participant commented:

> *"As you can see Flower Action sent several people to the event. They [Flower Action] are doing network business- pulling all kinds of data together and organising. They are (refers to OPHC and Light Speed) competitors, so they (OPHC and Light Speed) do not talk further".*
>
> *Interview with a senior engineer in Delta City, 18 March 2016*

Boschma provides some explanation of this phenomenon. He argues that *cognitive proximity* that is too close or too far is not good for communication. A certain level of cognitive distance is necessary as it might give rise to novelty. However, if the cognitive distance is too close, it increases the risk of involuntary spill over (Boschma, 2005: 64). As see above, without a pre-existing relationship of trust, the similar interests between two companies actually acted as a barrier to communication. Both parties were concerned about their own copyright and were not overly open for communication.

People's private expectations was another reason that influenced the *articulation of the vision*. For example, there were some actors who had a certain degree of network knowledge and were not in competition with OPHC. It was also difficult for them to buy in to the vision of OPHC, because those participants had strong private expectations and those expectations set their priorities in searching for specific technological solutions for their own businesses. A good example of this type of actor is a local engineer, Lao Zhao. Lao Zhao knew about the trend of network convergence, but he was overly focused on finding a particular technical component for his own project, as the interview extract below reveals:

> *"I am clear about the development direction of Operating Systems which is everything convergence. An operating system in his talk is actually a network controller system. The name confused me. I thought whether it is hardware or software? I asked him if it can control or define the sensors. He always talks about Wi-Fi. To be honest, Wi-Fi uses very little in a project. I am not very interested in that (...). I thought they know Li-Fi technology (...). My project about hospitals and prison are looking for the Li-Fi solution. In a building, temperature, air conditioning, light and building management all have individual signals. The protocols we use is hard to define. I thought they [OPHC]could define all signals. I asked, 'can you define sensors?' But he only talks about the operating system and Wi-Fi (...)."*
>
> *Interview with Lao Zhao in Delta City, 18 Mar 2016*

From the interview extract we can see that Lao Zhao has some shared knowledge background with the recent communication network development, but he was narrowly focused on finding solutions to define all the sensors in a building and not interested in the Wi-Fi network and 'City OS' that were promoted in the vision of OPHC.

(6) Visiting Delta City Day3

On the last day, delegates visited Delta City's national supercomputer centre. After seeing the world's fastest supercomputer, they had a three-hour meeting with DCIIC and some local organisations. Chris again articulated the vision of OPHC. The content of the speech was similar to that which he had delivered a few days' ago. Three Professors from two local Harbour City Universities also talked about their research on 'smart cities', including high-performance networks, big data analysis, and driverless cars. On the Delta City side, the presentation themes consisted of the supercomputer, e-health, intelligent streetlighting, and data exchange.

We can find some clues about how Delta City side reacted to the OPHC presentation in Director Ma's final comments at the meeting. He clearly expressed three areas that he wanted to cooperate with Harbour City and OPHC. First, he still thought that SOFT's smart street lighting solution was related to OPHC and would like to see future collaboration. Second, he thought that the Data Exchange company in Delta City could use Harbour City University's expertise in data analytics. Thirdly, he expressed interest in driverless cars. Director Ma's choices reflected a series of issues that I have mentioned above. Director Ma has little free agency to choose what technologies the DCIIC wants to incorporate in their smart city project as the hierarchical organisational structure he is embedded in has close *organizational proximity*. His decision making has to be in line with macro expectations in China. For example, the smart street lighting solution responds to the macro- expectation of exportation of technology products. To increase the data analytical ability of Data exchange companies resonated with the national "*big data strategy*". The interest in driverless cars follows the macro expectation of "*Made in China 2025*", especially the increasing interest in robotics.

After the delegation's visit, the Harbour City to Delta City smart city project came to an end. A report was written by Andy to feedback to the FCO. The delegates got together again when they got back to Harbour City in April 2016 to reflect on the delegation visit. They had complex feelings about the delegation visit. On one hand, they were impressed by Delta City's development and its supercomputer facility. On the other hand, they realised that persuading the Delta City authority and companies to buy into the vision of OPHC was more difficult than they had thought. This was due to many reasons: the different understanding of technologies, the lack of commitment on both sides, and a series of macro expectations in China that have to be taken into consideration. However, the diffusion of OPHC to Delta City was not regarded as a failure. They certainly spread the name of OPHC and Harbour City to the other side of the world. Also, they did not claim the diffusion as a failure. They learnt something in the process: that they should have more focused communication and commitment in the future.

7.3 Discussion

This chapter investigates the early diffusion process of OPHC. It investigates two diffusion directions: diffusing OPHC to general global smart cities audiences and diffusing OPHC to a specific city. In this section, I first summarise characteristics from two diffusion process, such as their purposes, methods, and results. Then, I conduct further analysis on two issues that appear in both diffusion directions: the contradiction between increasing global reputation and local hypes; and the challenges of diffusing OPHC to Delta City.

7.3.1 The characteristics of the diffusion

Drawing on Strategic Niche Management (SNM), I conceptualise vertical diffusion as an *aggregation* experience from a local smart city niche (OPHC) to a global smart city niche. I frame the horizontal diffusion as a process of spreading the vision of one *local niche* (OPHC) to another *local niche*. The smart city is an emerging global phenomenon without stable rules and standards at the global smart city niche level. At a local level, there are many local smart city niches. Local smart city niches like OPHC and DCIIC's smart city project all seek to *aggregate* their best ideas to the global smart city niche. For example, OPHC want to spread its idea of a programmable infrastructure, citizen engagement, and 'Fun City' to the global smart city niche. DCIIC wants to promote its smart street lighting solution to the global smart city niche. By doing this, they each want to become a leader in the world of smart cities and legitimate their practices as the best practice for other cities to learn from. Alongside local smart cities niches aggregating their best practices to the global smart city niches, *local niches* are not passive receivers of smart cities visions from outside. Instead, they seek to diffuse their ideas to each other. This is evidenced in the smart cities communication between Harbour City and Delta City. Both parties sought to directly sell their smart city applications (e.g. SDN controller and the smart street lighting solution) and vision to each other (**Figure 41**).

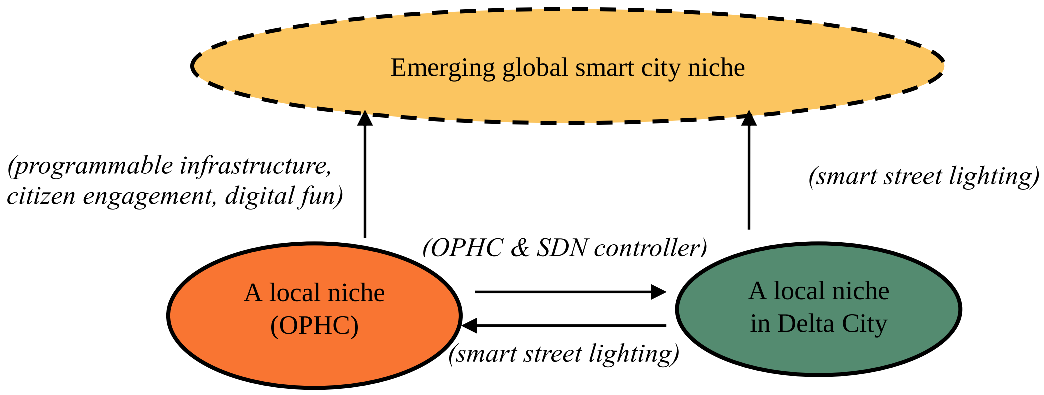


Figure 41. *The overview of both diffusion directions*

In both diffusion directions, OPHC's diffusion was mainly about diffusing the vision of OPHC rather than a single technology product (e.g. a smart application). This was partly because OPHC remained at the vision stage, partly because OPHC is a system innovation involved in a series of inter-connected technological elements and social infrastructures. Although some parts of OPHC could be sold as a product (e.g. SDN controller), the overall project is difficult to sell as a product. The purpose of diffusing OPHC to the global smart city niche is to attract global attention and to help OPHC to gain potential support. The purpose of diffusing OPHC to Delta City was get Delta City officials and companies to buy into the vision of OPHC. So that they either test their products through the OPHC testbed or purchase the SDN solution to build their own programmable network.

In both diffusion directions, the method of diffusing OPHC was articulating the vision of OPHC through speeches. As seen above the vision of OPHC was voiced through different infrastructures or channels. At a global level, the vertical diffusion team (e.g. Chris, Susan, Ruby) voiced the vision of OPHC through many smart cities conferences. While to Delta City, the horizontal diffusion team voiced the vision of OPHC through the communication channel of the EU-China smart city programme. The vision of OPHC was articulated iteratively in two webinars, on delegation visit days 2 and 5. In order to attract attention and establish OPHC in a leading position in the current smart cities movement, the vision of OPHC was often inflated. For example, they presented the vision as if it were already a reality. The rhetorical use of "*first*" was also used in almost all the OPHC related speeches.

As a result, the actions of diffusing OPHC to the global smart city niche were quite successful. It helped OPHC attract a lot of attention from actors at a global level. They regarded OPHC as inspirational for the current smart cities movement, particularly its elements of citizen engagement and the 'Fun City' idea. They also gave OPHC two prestigious smart cities awards. However, interestingly, while OPHC was regarded as a leading role model at the global smart city niche level, it generated disappointment for people at the local level (Harbour City). The goal of diffusing OPHC to Delta City was also relatively disappointing. I would like to unpack both aspects below.

7.3.2 The speed of hype at different levels

Diffusing OPHC to the general global level was very successful, however the growing global reputation of OPHC stands in contrast to the increasing disappointment experienced by local host partners. This contradiction is another example of the *paradox of vision* whereby the performance of its vision helped OPHC attract attention as well as create disappointment. Sociology of Expectation scholars (Borup et al., 2006) have studied similar phenomenon and call this temporal pattern of expectation/vision as the *hype and disappointment cycle* (Brown, 2003). They find that expectation/vision tends to be inflated by innovators at the beginning of an innovation to attract attention and mobilise resources. However, if the deployment of a vision in reality does not meet the promise, rising expectations will turn into hype. This will generate disappointment and damage reputations and trust in the project. Applying the *hype and disappointment cycle* to this case, it is not difficult to understand why the local host partner would have been excited about OPHC at the beginning and why this turned into disappointment. The inflated vision of OPHC helped OPHC attract attention from local host partners but when OPHC did not deliver on its promises, the vision of OPHC quickly turned into hype. A member of a local host partner expressed this disappointment; "*it [OPHC] is a digital fiction*" (Interview with an actor from OPHC local host partner, 30 June 2016).

However, the hype pattern shown in this case resonates with to Van Lente et al. 's (2013) observation that hype patterns can be observed at different levels: the micro level (project level), meso level (field level), and macro level (social level). As we have seen above, the hype of OPHC turned into disappointment faster at the micro level (project level) than at the field level (the global smart city niche). In addition to Van Lente's observation, I argue that the speed with which vision turns into hype is different at different levels and this is due to the environment that the vision of OPHC is embedded in. At a local level, the vision of

OPHC was situated in a social network that had an explicit expectation about the materialisation of the project. The inflated vision of OPHC quickly attracted many local actors to buy into the vision. These actors were close to OPHC and they had explicit expectations of OPHC. When certain aspects of OPHC were not realised as expected, they turned into disappointment immediately. For example, Straw House in the Harbour City bought into the OPHC vision and took actions towards realising it. As time passed, and OPHC's RF Mesh network did not open as planned, Straw House felt hugely disappointed with OPHC. At the global smart city niche level, OPHC was surrounded by smart cities actors who did not have explicit expectations of OPHC. The global smart cities niche is still at a stage of formation, so the delivery, or failure to deliver of the OPHC vision was not regarded as a priority. Actors at a global level did not expect to see any results from OPHC in that timeframe. They were more focused on finding novel examples and learning valuable lessons from different local smart city projects. So, it made no difference to them whether OPHC's RF Mesh network opened on time or not. Thus, we can see that, the inflated vision of OPHC helped to grow OPHC's global recognition. The 'not-yet' realised vision was regarded as a promising smart city vision which contributes a lot of fruitful thinking about how to make a city smart. Therefore, OPHC will continue to be seen as a promising smart city project at the global smart city niche level, until the environment at the global smart city niche changes and it generates more specific expectations about OPHC.

7.3.3 Different proximities harming horizontal diffusion

Comparing the success of diffusing OPHC to general smart city audiences, diffusing the vision of OPHC directly to another city (Delta City) was challenging. As shown above, although the vision was iteratively introduced to Delta City audiences, it was still difficult for the Delta City authorities and companies to buy into the vision of OPHC. I briefly applied Boschma's (2005) four types of *proximity* to understand some of the communication challenges and used Van Lente's (1993) levels of expectations to understand on Delta City's many types of expectations that appear in the communication process. Below, I elaborate them further.

Geographic distance was the first factor that made the diffusion process difficult. There are thousands of miles distance between the two cities. Using Boschma's (2005) term, there is no *geographic proximity* between the actors in two cities. The direct result of this is that communication between the two parties had to rely on a technologically mediated channel (webinar) and the delegation visit. The timing of the delegation visit was restricted by practical reasons, while the webinar communication experienced many problems, such as technology noises in webinar 2 so that participants could not hear or see each other's presentations clearly. Moreover, the technology mediated communication lacked the capacity for frequent interruption, that people cannot ask questions whenever they want. For example, as mentioned above, the audience in the Delta City side ended up with a different interpretation of the use of 'lamppost' and 'City OS'. Both terms needed actors on both sides to clarify. The nature of the technology mediated communication did not offer unrivalled capacity for interruption, repair, feedback, and learning (Coenen et al., 2010), so during the Webinar, people on both sides had little chance to interrupt, ask each other questions, and clarify concepts.

The second factor is *cognitive proximity.* A certain level of shared knowledge background was needed to make effective communication possible. The lack of *cognitive proximity* was an issue repeatedly in the communication process. First, as we saw DCIIC officials did not have *cognitive proximity* with OPHC. This was evidenced in both webinars and the delegation visit Day 2 and Day 5. From DCIIC's reaction, we see that they did not properly understand the vision of OPHC. In their mind-set, Internet of Things (IoT) is equal to 'smart cities'. It is not so farfetched to hold this belief as the idea of Internet of Things (IoT) is pervasive in today's smart city making. DCIIC is just following this trend. However, this cognitive schema lessened their understanding of OPHC. For example, because they regarded OPHC as a city scale Internet of Things network, when they selected topics to talk to OPHC about, DCIIC highlighted SOFT's smart street lighting application twice. DCIIC did not pay attention to the revolutionary programmable infrastructure at all in the entire communication process. Second, the translator and OPHC also did not have *cognitive proximity*. As we saw, the translator Li did not have background knowledge of SDN technology. So, she skipped over all the technological aspects of OPHC in her translation. Third, OPHC and the companies did not share *cognitive proximity*. As we saw in the interview with conference participants on visit Day 2, that they did not understand SDN and the idea of a programmable testbed.

However, too much *cognitive proximity* can also affect communication. Although Flower Action shares close *cognitive proximity* with OPHC, this did not make communication easier, because Flower Action is also an SDN promoter. OPHC and Light Speed did not want to elaborate on technological details with competitors. In order to make parties who share close *cognitive proximity* to have deeper communication, *social proximity* or *trust* is necessary. Moreover, good *cognitive proximity* between two parties also does not guarantee successful communication. This is because people's actions are driven by their private expectations as in the example of engineer Lao Zhao. Although he understood a bit about SDN and network OS, he was simply not interested in it because he overly was focused on finding solutions (e.g. Li-Fi) for his own business.

The third factor that effected the articulation of OPHC's vision to the Delta City actors, especially the DCIIC officials, was *organisational proximity*. According to Boschma (2005), *organisational proximity* means a set of interdependencies within and between organisations. *Organisational proximity* influences the degree of control and autonomy under which knowledge is exchanged and processed. Too much *organisational proximity* has the problem of lacking the flexibility to adopt new ideas because new ideas are not rewarded in a bureaucratic system and it is difficult to have interactive learning Intra- and Inter- organisations. One example of high *organisational proximity* is a hierarchically organised firm and network. While too little *organisational proximity* may increase the danger of opportunism. An example of loose *organisational proximity* is the joint venture form of firm and network. I argue that DCIIC and OPHC do not share similar *organisational proximity*. DCIIC is a government organisation in Delta City with a strict hierarchical structure, and situated in a bureaucratic system. On the contrary, OPHC is a joint venture between the University of Harbour City and Harbour City Council. It is a loosely coupled network in a local context. The interaction between OPHC and DCIIC could be regarded as an interaction between two different types of *organisational proximity*: the loose *organisational proximity* and the high *organisation proximity*. Since DCIIC has a high *organisational proximity*, it has less flexibility to choose the innovation pathway it wants. So, when the vision of OPHC was presented in front of DCIIC, DCIIC officers would have had difficulty buying into the vision of OPHC according to their own free will.

The fourth reason effecting the articulation of the OPHC vision is *social proximity*. *Social proximity* is the social relations between agents at the micro-level based on friendship, kinship and experience. Boschma (2005) argues that too much *social proximity* creates a lock-in effect and 'mytopia'. It may lock members of social networks into established way of doing things and have adverse impacts on their own innovative and learning capabilities. On the contrary, too little *social proximity* make it difficult for both parties to communicate with each other and exchange tactical knowledge because trust between actors is required before they will commit their resources and knowledge (Coenen et al., 2010). I had mentioned that the lack of *social proximity* between Flower Action and OPHC made it difficult for the two parties to have an open conversation. The lack of *social proximity* was also an issue between OPHC and DCIIC officials. Although Delta City and Harbour City have 15 years friendship, these interactions were mainly at a senior level and not between two smart city niches (OPHC and DCIIC) at a local level. Moreover, the mayors in the two cities changed many times, so the personal connection was lost when the original people left. However, it takes time between two parties in an international cooperation, to build a relationship of trust before they commit resources. Plateau City provides a counter example; Plateau City is also a sister city of Delta City, and due to its long-term commitment to Delta City, it successfully built *social proximity* with Delta City. As a result, it has successfully tapped a lot of research funding from Delta City.

In addition to Boschma's conceptual tool *proximity*, I argue that there is another *proximity* that influences the diffusion process which is the *proximity of expectation*. As we saw above, OPHC encountered expectations in another cultural context in the diffusion process. Using Van Lente's (1993) classification, we can sort these expectations into different levels (micro-, meso-, macro-), OPHC directly encountered many micro level expectations in Delta City, including companies' micro expectations (e.g. Lao Zhao's expectation of finding a Li-fi solution) and DCIIC's smart city expectation (e.g. smart street lighting). OPHC also in-directly encountered many meso-level and macro-level expectations in China. For example, Delta City municipal government's expectations and the macro expectations in China (e.g. Made in China 2025). Expectations at the micro level guide innovators and firms to search for specific technology. So, the *proximity* between OPHC and those micro levels of expectation in Delta City would have a direct effect on the diffusion of OPHC. Expectation at the macro level will also have in-direct impacts on the diffusion process of OPHC. Its impacts mainly manifest through influencing the choice of technology at the meso and micro levels. As we saw above, certain technologies highlighted in the Chinese context connected with the culture's deepest hopes and fears. For example, robotic technology was prioritised by the Chinese government at that time, because it was assumed it could help China to upgrade its industry. As a result, this technology was scripted in China's macro agenda

"*Made in China 2025*". The macro expectations in China also influenced local government and civil servants in choosing technologies. For example, in webinar 1, after listening to the OPHC niche actors talking about the vision of OPHC, DCIIC picked up on the Robotic lab rather than the programmable infrastructure of OPHC. Another example happened in Day 5 of delegation visit. After Chris talked about OPHC vision, the responses from DCIIC were not about the programmable infrastructure, but a suggestion of cooperation around driverless cars. In both cases, the macro expectation of upgrading industry legitimated robotic technology as a promising technology for the future China. Macro expectations effect the choice of technology at meso and micro levels. So, in order to successfully diffuse OPHC, there also needed to be a *proximity* between the expectations of OPHC and the macro expectations in China. The closer OPHC related to those macro expectations, the more likely OPHC would have been to match with the expectations at the meso and micro levels in Delta City.

7.4 Conclusion

This Chapter investigated the phenomena of diffusion in the innovation process of OPHC. On one hand, OPHC innovators sought to spread OPHC to general global smart city audiences and become a leader for others to learn from. On the other hand, it wanted to mobilise OPHC to another local smart city niche in China. Both diffusion directions relied on the performance of the vision to spread OPHC. From the results, we can see that the vertical diffusion was quite successful because the emerging smart city field welcomed the new ideas from a local smart cities niche. The vision of OPHC brought fresh food for thought for the emerging global smart city niche. However, at the local level, the same performance of vision had already past the phase of excitement and turn into hype. This was mainly due to the different speed of hype at different levels. It turns into hype faster at the local level where people had brought into OPHC vision and had expected it to be realised sooner. In terms of the latter diffusion, although key OPHC actors iteratively introduced the vision of OPHC to Delta City companies and officials, it was difficult for them to buy into the vision. As analysed above the *geographical-*, *cognitive-*, *organisation-*, *social- proximities* all cause problems to the diffusion process and I also argue that a new form of *proximity* (*expectation proximity)* needs to be taken into account.

Chapter 8

Conclusion

8.1 Introduction

This research provided a detailed study of the making of a smart city OPHC, in terms of its emergence, implementation, and diffusion processes. Due to the time restriction of this research, it can only capture the very early stage of this smart city innovation. The moment when I left the field, OPHC was at its lowest point. This was partly due to it not delivering things it had promised and losing the trust of its local host partners. It was also partly due to external political turbulence in 2016 (e.g. Brexit and the local mayoral election) which brought some negative impacts to OPHC. For example, many of the innovators that we encountered in the stories had left OPHC by the end of 2016. New teams were being recruited around OPHC which had the ambition to restructure the project. However, some of these newly recruited actors were themselves replaced by others later on. It worth pointing out, the overarching vision of the Open Programmable Harbour City has been sustained even when innovators have left, specific elements of this idea in practice have not yet been achieved or were found to be undesirable. The story of OPHC continues and its future innovation directions depend on ongoing dynamic negotiations.

Looking back over the whole innovation process, it is hard to conclude the messy and fluid innovation process in one sentence. Nevertheless, there are still two overarching points that I could like to highlight. First of all, a smart city innovation is not just about the implementation of technology, instead, it is a type of *configuration* which continually evolves. Vision is an actor playing a dynamic and paradoxical role in the evolution process (e.g. attracting attention, coordinating actions, providing protection). The evolutionary results will likely differ from the original promise of the project. As we have seen with OPHC, many technological investments took longer than expected or were not realised; citizen engagement was limited in the innovation process; and the platform had not yet been sold to other cities. However, the story of this smart city innovation is more interesting that this would suggest. The innovation process generated other effects beyond its original plan. For example, at local level, the innovation process of OPHC has produced many artefacts (e.g. high-speed broadband, a newly upgrade 3D dome, and the Toad) and generated employment opportunities. It has also successfully mobilised some actors to take action (e.g. Straw House). At a global level, OPHC boosted the city's international reputation and established it as in a leading position in the smart city world.

Following this dynamic result, the second point becomes more understandable; that it is difficult to evaluate a smart city innovation. For a system innovation like a smart city, it is difficult to judge whether the difficulties are just temporary or a sign of hype. As we have seen above, although OPHC failed in its original promise, it produced other results. The negative results at the project level and the replacement of innovators will not challenge the whole assumption of the project. Innovators in OPHC can apply *interpretation flexibilities* to explain the negative results and the vision of OPHC will continue to provide protection for future experiments. They will create new agendas, conduct new experiments, and this likely will generate new problems. If the results are negative again, innovators can again apply *interpretation flexibilities*. This cycle will continue and repeat many times. If it produces something significant in the end, the vision of the smart city project will become a self-fulfilling prophecy. Otherwise, this cycle will stop when the vision is no longer promising, or the smart city is replaced by some new concept at global level. At that moment, the previous negative results will be re-interpreted as a failure.

In the following sections, I start by drawing together my observations in the preceding chapters to addresses the three core research questions. This will include: shedding light on the innovation process itself; discussing the dynamic and paradoxical roles that the vision of OPHC has played in the innovation process; and reflecting on how citizens were imagined, involved and excluded in the process. Then, I will discuss some of the limitations of the research and point out the potential future directions for both empirical exploration and theoretical development. This thesis concludes with some of my reflections about technological innovation and highlights the contributions of this research.

8.2 Addressing the research questions

8.2.1 RQ1: What are the innovation processes of a smart city project?

This research shows that the birth of OPHC differed from smart cities projects that we often read about in academic and popular literatures. Smart cities projects are usually either created in a top-down manner by technology corporations and authorities (e.g. Songdo, Rio de Janeiro), or simply re-labelled existing initiatives in a city in response to the trend of 'smart cities' (e.g. Turin). The birth of OPHC shows a much complex picture. OPHC was born in a local context which provided many pre-conditions for its emergence, including human actors (e.g. a network of innovators, and many institutions), technologies (SDN, supercomputer, dome), and many existing expectations (e.g. connecting the dome to the supercomputer; building up an experimental testbed). A network of local innovators constantly created *configurations* based on these pre-conditions in response to external innovation opportunities (e.g. the digital infrastructure competition). However, innovators' agency was both restricted and enabled by the broader structure those *configurations* were embedded in (e.g. the laws and regulations and the network industry). OPHC was a *configuration* of people, artefacts, expectations that *survived* in the selection environment at the local *niche* level. This OPHC *configuration* was then creatively linked to the global smart city trend. OPHC innovators enriched the *configuration* as a smart city project through the alignment of technologies, applications, local host partners, big corporations, and created a *prospective structure* (vision of OPHC) to envision it as a smart city project.

Following the unique birth process, OPHC proposed an open innovation model. This model aimed to provide a city-scale programmable infrastructure to enable an ecosystem of users (academic, business, local partners, citizens, and other cities) to experiment with smart solutions for urban problems. This model was partly informed by criticisms of other smart city projects that are thought to benefit only big corporations and authorities and leave little space for local people (Townsend, 2013; Holland, 2014). The OPHC innovators wanted to build a different kind of smart city project. A smart city with benefits for everyone. It was partly influenced by the characters of Harbour City; the city with an entrepreneurial spirit (Harbour City has many creative class in DOCK and SMEs in BOX) and an ethos of civic movements (e.g. Straw House). So, innovators of OPHC saw the potential that this open model might work in Harbour City.

The materialisation process of the OPHC happened at two levels. At the local level (Harbour City), three *sub-niches* were created by different innovation teams (OPHC engineering team, the OPHC business team, the Data Dome team, and the Citizen Sensing team). Each sub-niche relates to a different aspect of OPHC, such the programmable testbed, the first application in the Data Dome, and the Citizen Sensing application. Under the guidance of OPHC vision, innovators sought to create a network of actors within each niche through the *articulation of expectation*, *building social networking*, and *learning*. In the end, although each site produced some outcomes, none of them fully realised their roles as scripted in the vision of OPHC. Beyond Harbour City, innovators of OPHC sought to diffuse the 'not-yet' realised vision of OPHC to the world try and win global attention and support. Performing the vision was the main way used to diffuse the vision and this produced dynamic results. In the vertical diffusion direction, the performance of the vision helped OPHC establish a leading position in the global smart city niche. While, in the horizontal diffusion direction, the diffusion suffered due to the lack of many types of *proximity (geographical, cognitive-, organizational-, social-,* and *expectation*-). It is also worth noting that when OPHC became a global smart city success story, people in Harbour City had gone through the cycle of excitement, actions, and disappointments.

Overall, the assumption of building an infrastructure around which an ecosystem of actors would then form naturally was shattered in the real innovation process. This is primarily associated with two reasons: lack of mutual shared interest, and a lack of clear coordination. For the former, as have seen above that people, organisations, and culture have their own expectations. Where they could not find shared interest with OPHC, they tended to not take up the roles that the vision of OPHC had allocated for them. This was true of the SMEs in Delta City who did not want to experiment with OPHC and build applications for the Dome. This was also evidenced in companies and officials in Delta City not wanting to buy into the OPHC vision. For those who buy into OPHC vision, the second reason became obvious. As we can saw in Chapter 6, when people have taken up the roles that the vision of OPHC assigned to them, they have tended to translate OPHC according to their expectations. For example, the OPHC engineering team focused overly on keeping the infrastructure state-of-art rather than making sure that the infrastructure could be delivered in time for use by other actors, such as Straw House, who were driven by the goal of citizen engagement. In the case of the Data Dome, there were a number of competing interests - the Science Museum's desire to upgrade its facilities; the local authorities desire to generate jobs and see financial benefit. So, although different types of actors bought into the OPHC vision, OPHC had neither the authority nor the capacity to impose a clear coordinated plan and structure to the overall project. The whole project becomes characterised by a lack of communication between different niche developments, which went on at different speeds.

8.2.2 RQ2: How does the vision contribute to the innovation processes of a smart city?

Vision is an element which is often neglected in current smart cities research. There is often a dualist treatment of the vision that regard vision as something static and independent from smart city innovation processes. As a result, much smart city research either focuses on critiquing main stream smart cities visions (Holland, 2008; Vanolo, 2013), or exploring citizens' expectations of smart cities (Thomas et al., 2016). This research is based on a non-dualist attitude to vision and the innovation process. The ethnographic research provides me with a specific vantage point to look at what vision actually does in a smart city innovation process.

There are many expectations and visions that can be identified in the innovation process. For example, there were a series of expectations (e.g. Gigabit Harbour City, the experimental testbed, connecting the dome to supercomputer) that pre-dated the OPHC vision. There were OPHC related expectations, such as the expectation of building a programmable infrastructure, Data Dome, and commons approach to Citizen Sensing. There were also many co-existing expectations and visions, ranging from local developers' expectations of developing a system for the Data Dome, to macro expectation of "*upgrading industry*" in China. Amongst those visions and expectations, the overarching OPHC vision is the main vision in the innovation process. Based on the analysis above, I argue that OPHC vision plays a dynamic and sometimes paradoxical role in the emergence, implementation, and diffusion process of OPHC.

First, the OPHC vision contributed to a tidying up of the past as well as envision a future. In OPHC's emergence (Chapter 5), the vision of OPHC was created to tidy up the complex birth process of the project. It pulled together various expectations, actors, and technologies into a coherent story. It simplified the emergence process of OPHC and bundled together highly disparate interests into one seemingly coherent initiative. The vision of OPHC not only described what was already in the OPHC project, it also *scripted* roles for many groups (e.g. SMEs, citizens, other cities, etc.) and future artefacts (e.g. Data Dome, RF Mesh network, 'City OS', 'Network Emulator'). This *script* made up a *prospective structure* which projected to the future and sought to mobilise certain future arrangements to the present.

The second function of the OPHC vision was that it helped to mobilise some actors, but it failed to mobilise others. These *scripted* roles in the *prospective structure* appealed to some actors and successfully mobilised them to take actions. Many examples can be found in Chapter 6 and Chapter 7, such as Straw House, who took up the role to co-produce a Citizen Sensing application; and several engineers and corporations (e.g. JEP) found ways to use OPHC. However, the vision of OPHC failed to mobilise other actors. it failed because some actors (e.g. citizens) were not interested in the role assigned to them; It failed because the vision mis-interpreted actors' true needs (e.g. in case of SMEs); it failed because others did not understand the vision and they had competing ideas of what a smart city is and its purposes (e.g. the case of Delta City). It also failed to mobilise some non-human actors, for example, the layout of the Data Dome restricted the materialisation of the vision.

Third, the OPHC vision coordinated actions of the innovation team at each site, but it did not coordinate innovation activities between sites. As we can see in Chapter 6, the innovation activities in relation to OPHC mainly happened in three parallel sites: an infrastructure and two applications. The vision of OPHC contributed to coordinating innovation within each site through creating task divisions. Innovation teams in each site took the tasks that were assigned to them, built individual agendas, and took real actions accordingly. However, the vision of OPHC did not generate coordination between the innovation teams in the different sites. As seen above, the OPHC engineering team, the OPHC business team, the Data Dome team, and the Citizen Sensing team conducted broadly independent innovation journeys and there were no mutual agendas between them. As a result of the lack of coordination between innovation teams, negative influences impacted the realisation of the vision, such as the continued alignment of user cause frustrations for the OPHC engineering team; OPHC's business agenda affecting the *articulation of expectation* in Data Dome site; the application Data Dome not using the OPHC infrastructure; and the Citizen Sensing application developing faster than the OPHC infrastructure.

Fourth, OPHC vision nurtured innovation through providing a protected space but over protection also impeded innovation. The vision provided ongoing protections for the niche experimentation. It created a protected space through providing funding and ongoing narratives to allow actors, even when experiment results were negative, to continue arguing that the vision was being built. The setbacks were interpreted as a temporary failure on the road to future success. However, too much protection inhibits innovators to falsify their initial assumptions, open for negations, and to see what actually works in reality. As we can see in the case of Data Dome, the experiments had already suggested that it was a challenge for the dome to become an interactive data visualisation device. In reality, what worked best was using the upgraded dome for other purposes which has nothing to do with OPHC. However, the vision of OPHC still protected the insufficient idea and the poor design. In this case, the protection of the *niche* needed to be broken up and failure acknowledged for future success.

Fifth, the vision of OPHC contributed to attracting attention as well as causing disappointment. The vision of OPHC was voiced on many occasions and on different scales. In order to attract attention, sometimes, it was even inflated. As a result, the vision of OPHC success attracted attention from both local and global communities. For example, some people and organisations in Harbour City felt motivated to take part (e.g. developers and Straw House). It also attracted attention from the business and international smart city community. This is evidenced in the ongoing alignment of business partners and the awarding of two prestigious global awards. However, the vision also turned into hype and generated disappointment. It caused disappointment when it did not achieve what it promised. Straw House (Chapter 7), was excited enough by the vision to take action at the beginning, but, it became a disappointed when the RF Mesh network did not open as promised. Disappointment occurred when the *saying* and *readable action* did not match up. For instance, in the case of the Data Dome (Chapter 6). The performance of the vision was used to motivate many developers to participate, however the real actions (e.g. copyright arrangements and the demand for £1000 per hour development fees) contradicted the *saying* of the vision and put off many potential developers.

Therefore, this research suggests that the role of vision should be taken into account when theorising smart city innovation. Vision clearly plays many dynamic and sometime paradoxical roles in the earlier stages of smart city innovation where nothing is solid. In the case of OPHC, it both nurtured and impeded innovation. Innovators should be more aware of the power of vision and take it into account when managing smart city innovation, such as utilising vision wisely to foster innovation rather than impede it. It is worth noting, this research mainly focused on studying the vision of OPHC's role in the innovation process. There were other visions and expectations that can be identified in the process which would be worth future investigation.

8.2.3 (RQ3) How are citizens imagined and enrolled in the processes?

Many smart city initiatives circulated in publicity tend to emphasise what technology can do for future cities. Citizens are often treated as users in those proposed visions, rather than active agents. Research had already pointed out the absence of citizens in many smart cities initiatives (Hemment and Townsend, 2013; Townsend, 2013). Cowley et al. (2017) distinguish four modalities of publicness across six UK cities. However, we still lack a detail understanding about citizen engagement in an actual smart city innovation process. This research contributes to addressing this gap. It has analysed what kinds of roles were allocated to citizens in the OPHC smart city project, and to what extent citizens actually participate to enact those roles. The key finding is that citizens had limited roles in the OPHC innovation process and more intentional efforts would have been required to make citizens truly a part of the smart city project.

OPHC is an especially interesting case for the purpose of investigating the issue of citizen participation. This is because OPHC clearly positioned itself as different to technology-centric smart city initiatives and claimed citizen participation as a core principle. The vision of OPHC scripted roles for citizens in three places. The first is the programmable infrastructure. The vision of OPHC envisioned that everyone (including ordinary citizens) could experiment with the programmable infrastructure. Second, it suggested its first application, Data Dome, could be a space for citizens to engage with urban data, and for local developers to produce creative content. Third, it partnered with a local community organization, Straw House, to engage excluded communities. These three places reflected three roles for citizens. The first role is similar to what Cowley et al. (2017) calls the 'entrepreneurial sense of public' that expects citizens to create services and economic value through their creative use of digital infrastructure. Here citizens mainly refers to SMEs and developers who have certain technological know-how skills. There are two roles for ordinary citizens. One is aligning a mediator organization, Straw House, to co-produce applications with them. This is similar to what Cowley et al. (2017) call 'civic publicness'. This means activities that take place beyond state institutions. The other role is as interactive audiences. This idea was demonstrated in the case of Data Dome. This role is similar to Andrew Barry (2001)'s discussion about *citizens in technological society*.

Chapter 6 provided a detailed picture about how the three roles played out in reality. In general, the three roles assigned to citizens were not fulfilled. The first role was challenged at the sites of the programmable infrastructure and Data Dome. It was challenged due to the lack of 'middleware' that was necessary for SMEs and developers to access the testbed. It was challenged because not everyone was ready to participate in the experiment. For example, SMEs in BOX did not have technologies that are ready to test through OPHC; independent developers could not afford to spend time conducting experiments for the dome. It was challenged because the proposed idea proved to be unsuitable due to physical and financial barriers (e.g. the Data Dome). The second role was challenged because of the lack of coordination between infrastructure development and application development. As we have seen with the case of Citizen Sensing, the wireless infrastructure was not developed in time for the sensing application Toad to use. The third role was also difficult to realise. This is partly because it did not coordinate with OPHC infrastructure at all and partly because innovators realised that it did not make much difference to citizens to view urban data.

Overall, we can see that citizens played a limited role in the OPHC innovation process. Although the project stressed the importance of citizen engagement, citizen participation remained a rhetorical device, paying lip service only. In order to make a smart city innovation truly inclusive for citizens, efforts would need to be made to actually configure citizens in the innovation process. For instance, fundamental engineering decisions would need to be changed for this to be achieved. Co-creating should not merely for the purpose of exploring methodology, and more coordinated approach would need to be adopted.

8.3 Future research directions

Looking back at the process of this research, I can see several aspects in which the design could be improved. First of all, the goal of one researcher to conduct an ethnographic research about a smart city was too ambitious. OPHC is a system innovation happened in multiple directions. Although, I tried my best to follow the innovation process, there was some data I wanted to collect but was not able to. If I were designing it now, I would acknowledge the limitations of one researcher to do this research and seeking collaborations with other researchers for studying a big project like OPHC. Second, this research lacks a comparative angle. Although this is not the purpose of this research, it would be interesting to conduct comparative research with others smart cities innovation within UK and beyond. For example, I could to compare the case of OPHC with the smart city project Barcelona, because they both have some shared characteristics (e.g. open innovation) or with other UK smart cities' smart city making processes. I would also be interested to do comparative research between UK and China smart city making. Third, this research applied the socio-technical perspective of Transition Studies to understand the innovation process. As a researcher, I kept a distance from the innovation process, however, another approach could be to apply the Transition Management approach and work more closely with OPHC innovators to become part of the smart city innovation. Nevertheless, within this research, I have already opened many topics which are worth for investigation. I will specifically address the future theoretical and empirical directions below.

8.3.1 Future theoretical research

'Smart city' is an emerging research field which lacks robust theoretical frameworks. In order to find suitable theoretical frameworks for this research, I went through an *iterative-inductive* process of selecting, testing, modifying and assembling conceptual tools. An initial theoretical framework was pulled together from Actor-Network Theory (ANT), Andrew Barry's concepts, and the Sociology of Expectation, the Sociology of the Future. The approaches responded to key concerns of the research: process, vision, and citizens. However, the ongoing empirical work revealed the drawbacks of this initial theoretical configuration. For example, ANT is useful to spot the alignment mechanism in the innovation process, but it not so useful in addressing other elements, such as the structure limitation that OPHC faced, the diverse experiment and learning process, and the communication process beyond the territory. Andrew Barry's concepts of *technological zone* and *citizens in technological society* was also not suitable for the case of OPHC because OPHC was not mature enough to form a unified standard and deliver the interactive citizen engagement technologies. To modify the original framework and make it more suitable for the chosen case, I turned to the socio-technical Transition Studies. It shares some similar roots with STS (including ANT) and the Sociology of Expectation. I found its analytic tools, Multi-level perspective (MLP) and Strategic Niche Management (SNM) more useful for this research. I kept the Sociology of Expectation to complement Transition Studies' understanding of expectation and vision. In the end, I creatively re-configured the conceptual tools from the socio-technical perspective of Transition Studies and the Sociology of Expectation to create a theoretical perspective for the research. This framework has been useful to make sense of the innovation process and the role of vision in the case of OPHC. However, the conceptual tools from both approaches were created from historical cases. Applying them to a real-time case has generated some fresh insights which could be further explored as follows:

(1) Future research on the Transition Studies

The empirical data of this research could contribute to Transition Studies. In this research I applied MLP and SNM to shed light on the empirical data. For example, I adopted MLP in Chapter 5 to understand the emergence of OPHC. I use SNM in Chapter 6 to understand the innovation process in the three sites and to understand the case of Delta City in Chapter 7. Although, this research only observes the early transition process which made it difficult to judge the whole transition process of OPHC, the empirical observation can still contribute to understanding micro level innovation processes and their interactions with the *regime* level. The empirical data suggests that the conceptual tools could be further developed in three aspects.

- First, more research is required to understand the interaction between one *local niche* and multiple *regimes*. As above have been seen that OPHC is a local smart city niche, but it wants to change not only one *regime*, but multiple *regimes*, including the *regime* of urban management and the *regime* of the communication industry. Future research could look at the process of one local *niche* that transforms multiple *regimes*. The results of this exploration might enrich the understanding of the transition trajectory.

- Second, research is needed to explore the relationship between the *niche* and *sub-niche*. In the case of OPHC, under the overarching niche OPHC, there were three novel innovations. I have called them *sub-niches*. The research indicated that a niche can also have a sub-structure which I called *sub-niche*. Therefore, future research could explore the structure within an innovation niche, such as the relationship between two *sub-niches,* or the relationship between *niche* and *sub-niche*. It is increasingly necessary to understand more about these relationships because many innovations nowadays are system innovations which require the coordination of multiple sub-innovation systems (*sub-niches*).

- Third, more research is required to understand the *proximity of expectation* in spatial niche development. In studying niche expansion (Chapter 7), I applied Boschma's *proximities* to understand the articulation of vision in another cultural context. However, Boschma's *proximities* were created based on empirical data in one cultural context (e.g. Netherlands). The multi-cultural context of this research enriched Boschma's concept *proximity*. It suggests that *proximity of expectation* is another factor influencing the articulation of vision. This factor could be explored further.

(2) Future research on the Sociology of Expectation

This research also contributes to the Sociology of Expectation research. It largely draws on conceptual tools from the Sociology of Expectation to understand the role of vision in the innovation process of OPHC. This was extremely helpful to shed light on the dynamic roles that vision played in the innovation process. However, applying the conceptual tools in a real-time case generated new insights which could be further explored.

- The empirical data in this research could enrich the conceptual tool, the hype cycle. First of all, it provided rich data to show that *hype and disappointment* can operate at different levels. Van Lente et al. (2013) find that hype is constituted at different levels. Their research was based on public discourses about a certain technology over 10 +years. This research provides a zoom-in picture of how hype can come out at different speeds at different levels. Due to the timeframe of the research, it not possible to capture what follow up on local people what happened afterward when local people feel disappointment. Van Lente et al. (2013) suggest that misalignment of disappointment at different levels might contribute to a productive reconfiguration of expectation. In another words, that disappointment emerges at the local level faster that at the global level might be a good sign. It can stimulate innovators at the project level to conduct some productive recovery after the disappointment. Future research could follow this line of inquiry. Second, this research also suggested that the "precise expectation of a project" in an innovation environment is another factor that effects the hype patterns. As we can saw in Chapter 7, the specific expectations about OPHC at the local level was disappointing to local partners and developers. While at a global niche level, this specific expectation did not exist. So, global actors did not experience disappointment.

- Different cultures have different macro agendas in relation to technologies at different times which influences their choices of technologies at the meso- and micro level. In the case of Delta City, I applied Van Lente's (1993) levels of expectations to distinguish three levels (macro-, meso-, and micro-) of expectations that OPHC encountered in Delta City. In this case, OPHC as a micro expectation in one cultural interacted with level of expectations in another culture context. The research argued that the lack of *proximity of expectation* was another reason effecting the diffusion of the vision of OPHC to Delta City. Further research is required to explore the levels of expectations in different cultural and spatial context. This would contribute to our understanding about diffusing one vision from one culture to another.

- Further research is required to understand the immaterial or fluid aspect of a vision. The Sociology of Expectation looks at the present and the future in a form of past futures and present futures (Adam, 2005). This way of thinking about the future might neglect other aspects of the future such as the immaterial-, latent-, and immanent-, and invisible- future. Empirical data in this research shows that vision is fluid and can exist in an immaterial state. For example, the vision of OPHC was built on a series of pre-existing expectations in Harbour City. One expectation can merge or add to another expectation in order to survive in reality. Sometime, an expectation can exist in ideational space for a long time and this latent future might become concrete when conditions are ready. For example, the expectation of connecting the dome to the supercomputer had existed for a long time, but, it did not materialise until the opportunity of OPHC emerged. To study immaterial expectation and trace its materialisation process could enrich the sociology of expectation's understanding of the future.

- Attention is required to study the negotiation process between a proposed collective vision and other co-existing individual/collective visions. Most sociology of expectation research focuses on exploring collective/shared expectations and seldom pays attention to the interactions between collective expectation and other co-existing visions (Berkhout, 2006). In this research, I mainly look at the vision of OPHC, however, we can find many co-existing visions/expectations. For example, in the Data Dome site, we see that there were a lot of private expectations about how to utilise the newly upgraded Dome. Further research could investigate the ongoing negotiation process between collective/shared expectations and other visions. It is necessary because it will contribute to what we call a democracy of expectations.

8.3.2 Future empirical research

This empirical research mainly focuses on investigating the innovation process, vision, and citizen participation. However, in the research process, I noticed some other aspects which were not the main themes of this research but could be explored further. Below, I highlight four directions for future empirical research.

First, gender in smart city innovation is an issue which could be explored further. In the OPHC case, we can see a clearly male dominated landscape. For example, apart from the Chief Technological designer Susan, two directors of Straw House, a few of the staff from the city council, and one business manager of OPHC, the rest of the innovators were male. Further empirical research could be done in terms of how gender shapes the vision of a smart city project or how gender influences the innovation process of a smart city.

Second, this research studies non-human actors (e.g. technological artefacts) in the innovation process. As we have seen there are many non-human actors in the innovation process, including the H-Net, RF Mesh network, the dome, the supercomputer, and the Toad. To some extent they all have the capacity to shape the innovation process. For example, H-Net is the foundation of the OPHC project. It is impossible to imagine OPHC without it, because the cost of laying all the fibre would be very expensive. I briefly address their roles in this research, though more empirical research is required to explore how non-human actors react to the roles that vision assigns to them.

Third, the case of OPHC provides a great opportunity to explore ‘experimental city’. Because the key idea underpin OPHC was to provide an experimental testbed for people to explore technological solutions for future cities. This idea resonates to what Evan, Karvonen, and Raven (2016) called experimental way of knowledge production about the city. This new way of knowledge production differs from traditional urban knowledge production because it has a strong natural sciences commitment. For example, we can see a strong positivist language in the idea of the experimental research testbed, such as sampling, scaling up, and replicating. Maarten Hajer argued that the experimental form of knowledge production changes the epidemiology of knowing. The epidemiology of “*analysis and instruction*” has been replaced by an approach of “*variation and selection*”. The deductive logic of applying a genetic principle at the local level has given way to a more inductive way of knowing (Evan et al., 2016). There is a growing literature on ‘experimental city’ and ‘urban experimentations’ (Gross and Krohn, 2005; Gross and Hoffmann-Riem, 2005; Bulkeley and Castán Broto, 2012; Karvonen and van Heur, 2013; Evans and Karvonen, 2013; McLean et al., 2016). So far, there is no empirical data to shows that OPHC’s infrastructure produces certain knowledge about the city. However, if they do in the future, OPHC is a vintage point to explore the experimental way of urban knowledge production.

Fourth, OPHC is a good case to explore open innovation model. As we can see from the case that OPHC wants to build an infrastructure platform that enables an ecosystem of users to benefit from it. It also pays attentions to citizens and want citizens be part of its innovation model. OPHC resonates to some pioneer research in the area of called open innovations. For example, Ojasalo J and Tähtinen (2016) explored urban innovation platform which mediated a city and external actors. Some research explores public, private and people (PPP) open innovation model (Paskaleva, 2011; Ojasalo J and Kauppinen, 2016). Hans Schaffers explores an open innovation model that incorporate Future Internet technologies and cooperation of citizens (Schaffers et al., 2011(a); Schaffers et al., 2011(b)). OPHC is a good case to enrich some of our understanding about this open model of innovation, in terms of infrastructure’s mediator role; public, private and people (PPP) partnership. As we can see from above analysis, the most difficult part of OPHC’s open model is that it lacks coordination between different innovators. Actors, institutions, cities that assumed could become part of the ecosystem did not buy into the vision. Further research required, such as what kind of innovation management or co-envisioning activities could make the open innovation model work in reality.

8.4 Concluding Thoughts

My interest in studying the relationship between technology and society motivated me to do this research. On reflection, conducting this study has not only fulfilled this initial goal, but also shaped some of my understanding of technological innovation. I have realised that the technological innovation process is much more complex than perceived and is unlikely to happen in a linear fashion. Therefore, we should not panic when we hear a promising technology in the media that claim you will be excluded from the future if you do not follow it. As this research suggests, a promising technology will not necessarily bring immediate social change. Instead, the implementation of a technology is a *configuration* that continually co-evolves with many elements. Social change is a result of the *configuration* that matures enough to replace the existing *configuration* at *regime* level. This also suggests that a vision has dynamic and paradoxical roles in the innovation process. The future is not determined, we still have the power to *translate* visions and negotiate with them. Moreover, as a Chinese person studying a UK smart city innovation with a special link to a Chinese city (Delta City), I am in the advantageous position of having a comparative understanding of smart city innovation in two cultural contexts. I have realised that both innovation models have their trade-offs, which suggests a different way of looking at failure. For example, network driven smart cities model in Harbour City (UK) did not appear to deliver many things, but did enable a wide range of actors in the city to discuss and negotiate their own interests. It is possible that nothing significant happen and resources are wasted, but it may forestall other blind alleys that may generate more problems in the future. A technological solution in Delta City may be implemented very quickly and sometimes even deliver exactly what is promised. A drawback of the model is that it might provide limited space for wider civic discussions, and there is considerable risk if anything goes wrong.

Aside from self-reflection, I would also like to reflect on the overall contributions that the research has made in terms of knowledge and practices. This research creatively deploys an ethnographic approach and assembles conceptual tools from Transition Studies and the Sociology of Expectation to understand a smart city making. This research not only fills the knowledge gap in terms of the understanding of the innovation process and citizen participation in “smart cities”, but also demonstrates the dynamic and sometimes paradoxical roles that vision plays in the innovation process. The rich empirical data and detailed analysis contribute to our understanding of the “smart cities” phenomenon and allow for reader interpretation. This research also provides much practical guidance for smart city innovators, such as the issue of coordination, the power of vision, and citizens’ participation. The detailed presentation of how this research has been carried out could be a “guidebook” for those who want to use the ethnographical approach to their research. This research not only illustrates the samplings and creative analysis process, but also provides an example of how researchers make choices and deal with dilemmas in the research process, such as the relationship between ethics and research; the balance between science and art. Moreover, this research opens doors for future empirical and theoretical inquiry, such as the role of vision in Transition Studies, the geographical dimensions of niche development, hype patterns, the cultural dimensions of expectations, the open innovation model, and experimental cities.

Appendix **A**

Appendix 1. The full list of key fieldwork

OPHC infrastructure — Data Dome — Citizen Sensing — History of OPHC

Performative role of vision — Diffusion OPHC to Delta City

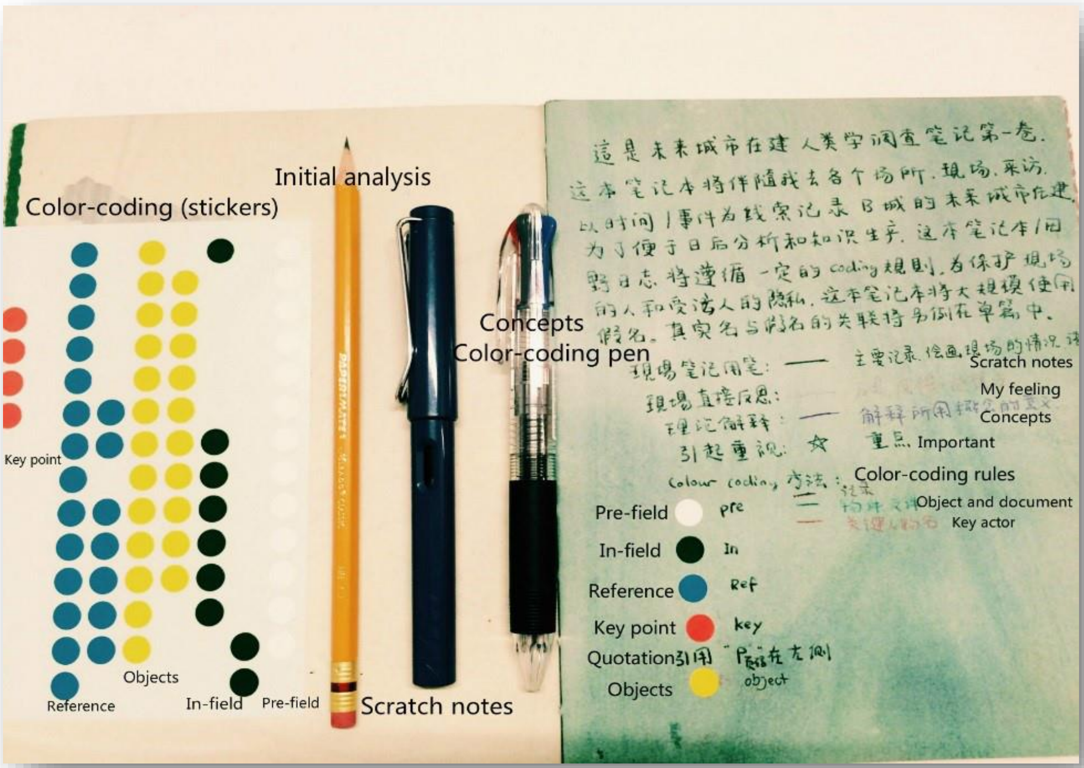
No.	Names of the Fieldworks	Data Collection method	Time	Theme
1	Meeting the Chief Designer of OPHC (Susan)	Informal Interview	08-May-15	OPHC infrastructure
2	Data Dome Workshop 1	Participant Observation	22-May-15	Data Dome
3	Urban Research Meeting	Participant Observation	04-Jun-15	
4	Local technological innovation exhibition	Participant Observation	09-Jun-15	
5	Harbour City to Delta City Webinar 1	Participant Observation	02-Jul-15	Diffusing OPHC to Delta City
6	Harbour City Internet of Thing event	Participant Observation	06-Jul-15	Performative role of vision
7	Software Defined Network workshop	Participant Observation	07-Jul-15	OPHC infrastructure
8	Harbour City to Delta City meeting	Participant Observation	10-Jul-15	Diffusing OPHC to Delta City
9	Informal interview with an Engineer(Pink) from the Next Lab	Informal Interview	14-Jul-15	OPHC infrastructure
10	My society meet up	Participant Observation	23-Jul-15	
11	Data Dome Workshop 2	Participant Observation, Informal interview	29-Jul-15	Data Dome
12	Vising the Next Lab, Informal interview with one Engineer, Chat with the head engineer (David)	Participant Observation, Informal Interview	05-Aug-15	OPHC infrastructure
13	Harbour City to Delta City Webinar 2	Participant Observation	07-Aug-15	Diffusing OPHC to Delta City
14	Formal Interview with an Engineer from the NEXT Lab	Formal Interview	23-Aug-15	OPHC infrastructure
15	Harbour City to Delta City Webinar 3	Participant Observation	24-Sep-15	Diffusing OPHC to Delta City

16	Chinese Delegation visiting (including visiting the Dome, Tele-health house)	Participant Observation	21-Oct-15	Diffusing OPHC to Delta City
17	Delta City Delegation visiting Harbour City	Participant Observation	22-Oct-15	Diffusing OPHC to Delta City
18	City Leadership Summit	Participant Observation	23-Oct-15	
19	Future City Festival Day 1	Participant Observation	16-Nov-15	
20	Future City Festival Day 2	Participant Observation	17-Nov-15	
21	Future City Festival Day 3	Participant Observation	18-Nov-15	
22	Launch event of the Data Dome	Participant Observation, Informal interview	18-Nov-15	Data Dome
23	Future City Festival Day 4	Participant Observation	19-Nov-15	
24	Future City Festival Day 5	Participant Observation	20-Nov-15	
25	Harbour City API	Participant Observation	23-Jan-16	
26	Citizen Sensing Networking Night	Participant Observation	27-Jan-16	Citizen Sensing
27	Delegation visiting preparation 1	Participant Observation	18-Feb-16	Diffusing OPHC to Delta City
28	Gigabit Harbour City Launch	Participant Observation	18-Feb-16	
29	Delegation visiting preparation 2	Participant Observation	19-Feb-16	Diffusing OPHC to Delta City
30	Data and Healthcare	Participant Observation	22-Feb-16	
31	Formal Interview with a member of Data Dome team	Formal Interview	23-Feb-16	Data Dome
32	Citizen Sensing workshop 1	Participant Observation	05-Mar-16	Citizen Sensing
33	Flying to Delta City (preparation)	Participant Observation	16-Mar-16	Diffusing OPHC to Delta City
34	Harbour City delegation visit Delta City Day 1	Participant Observation, Informal Interview	17-Mar-16	Diffusing OPHC to Delta City
35	Harbour City delegation visit Delta City Day 2	Participant Observation, Informal Interview	18-Mar-16	Diffusing OPHC to Delta City
36	Harbour City delegation visit Chan City Day 3	Participant Observation, Informal Interview	19-Mar-16	Diffusing OPHC to Delta City
37	Harbour City delegation visit Delta City Day 4	Participant Observation, Informal Interview	20-Mar-16	Diffusing OPHC to Delta City
38	Harbour City delegation visit Delta City Day 5	Participant Observation, Informal Interview	21-Mar-16	Diffusing OPHC to Delta City
39	Post-visiting de-brief	Participant Observation	08-Apr-16	Diffusing OPHC to Delta City
40	VR conference	Participant Observation	12-Apr-16	
41	Citizen Sensing workshop 2	Participant Observation, informal interview	16-Apr-16	Citizen Sensing
42	Maker Chinese delegation	Participant Observation	19-Apr-16	
43	Formal interview with a broad member of OPHC (Brown)	Formal Interview	10-May-16	Performative role of vision
44	May Digital week -Data Dome re-launch	Participant Observation	13-May-16	Data Dome
45	Informal Interview with a game designer	Informal Interview	13-May-16	Data Dome
46	Formal Interview with a civil	Formal Interview	19-May-16	History of

	servant from Harbour City council			OPHC
47	Open Data Challenge	Participant Observation	21-May-16	
48	OPHC tech meet up	Participant Observation	26-May-16	OPHC infrastructure
49	Formal Interview with a computer scientist	Formal Interview	06-Jun-16	Data Dome
50	Formal Interview with the Director of Dock	Formal Interview	15-Jun-16	History of OPHC
60	Formal Interview with a civil servant from Harbour City Council	Formal Interview	27-Jun-16	History of OPHC
61	Informal Interview with a staff from the Light speed	Informal interview	27-Jun-16	OPHC infrastructure
62	Formal Interview with a co-director from Straw House	Formal Interview	29-Jun-16	Citizen Sensing
63	Formal Interview with the Chief Manager of OPHC	Formal Interview	30-Jun-16	History of OPHC
				Performative role of vision
64	Informal group interview with engineers from the MiniCat	Informal Interview	30-Jun-16	Data Dome
65	Formal Interview with a co-director from Straw House	Formal Interview	30-Jun-16	Citizen Sensing
66	Citizen Sensing data workshop	Participant observation	09-Jul-16	Citizen Sensing
67	Informal Interview with a project manager of the Citizen Sensing	Informal Interview	09-Jul-16	Citizen Sensing
68	Informal Interview with Michael	Informal Interview	09-Jul-16	Citizen Sensing
69	Informal Interview with the designer of the Toad	Informal Interview	09-Jul-16	Citizen Sensing
70	Formal interview with the Chief Technology Designer of OPHC	Formal Interview	21-Jul-16	OPHC infrastructure
				History of OPHC
71	Formal Interview a project manager of OPHC	Formal Interview	25-Jul-16	OPHC infrastructure
72	Formal Interview with a researcher from the Next Lab	Formal Interview	04-Aug-16	OPHC infrastructure
73	Formal Interview a researcher from the Next Lab	Formal Interview	08-Aug-16	OPHC infrastructure
74	Informal Interview with the designer of the Toad	Informal Interview	10-Aug-16	Data Dome
75	Formal Interview the director of the BOX	Formal Interview	15-Aug-16	History of OPHC
76	Formal Interview the business manager of OPHC	Formal Interview	23-Aug-16	OPHC infrastructure
77	Formal Interview a researcher from the Next Lab	Formal Interview	05-Sep-16	OPHC infrastructure
78	Toad Talk in the DOCK	Participant Observation	02-Sep-16	Citizen Sensing
79	Straw House take over the Data Dome	Participant Observation	07-Sep-16	Data Dome

80	Interview the manager of OPHC	Formal Interview	21-Sep-16	History of OPHC
81	Tech meet up for LoRa WAN (1)	Participant Observation	12-Sep-16	Citizen Sensing
82	Formal Interview the Designer of the Toad	Formal Interview	13-Sep-16	Citizen Sensing
83	OPHC workshop	Participant observation	14-Sep-16	OPHC infrastructure
84	Formal Interview the head of OPHC engineering team (1)	Formal Interview	14-Sep-16	OPHC infrastructure
85	Formal interview the head of OPHC engineering team (2)	Formal Interview	16-Sep-16	OPHC infrastructure
86	Exploring the Brain in the Data Dome	Participant Observation	29-Sep-16	Data Dome
87	Formal interview an owner of SME	Formal Interview	03-Oct-16	Data Dome Citizen Sensing
88	Formal interview a member of the Data Dome team	Formal Interview	05-Oct-16	Data Dome
89	Harbour City Open Data Challenge	Participant Observation	08-Oct-16	
90	Informal interview with an engineer from MiniCat	Informal Interview	08-Oct-16	Data Dome
91	Tech Meet up for LoRa WAN (2)	Participant Observation	17-Oct-16	Citizen Sensing
92	Formal interview a member of the Data Dome team	Formal Interview	20-Oct-16	Data Dome

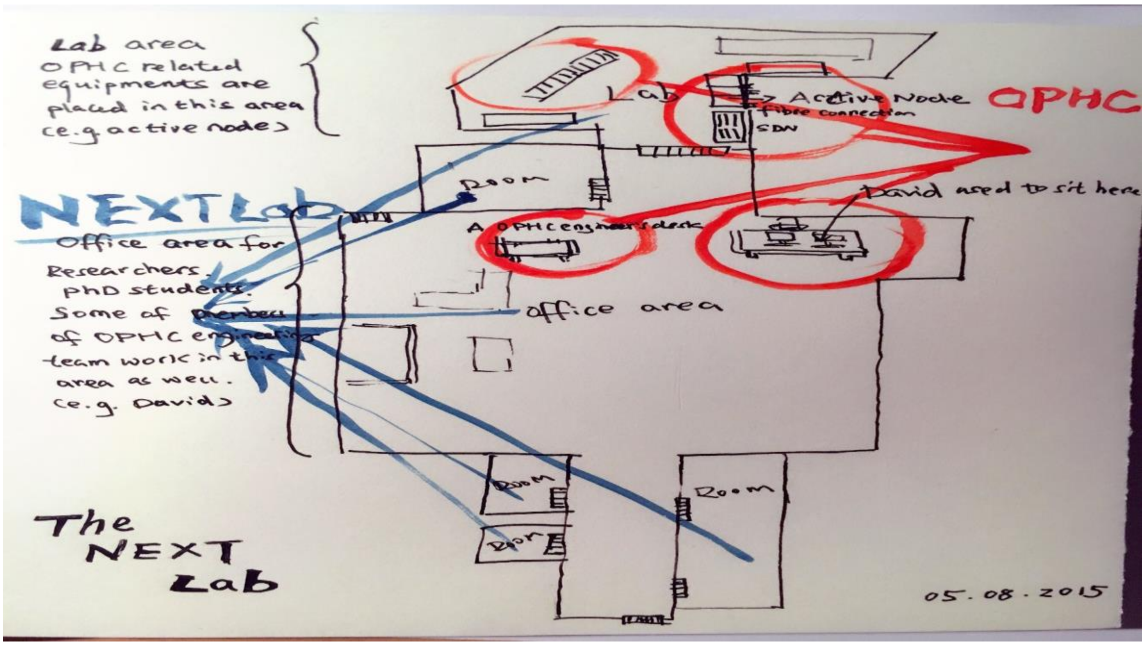
Appendix 2. The colour coding system of the observation notes



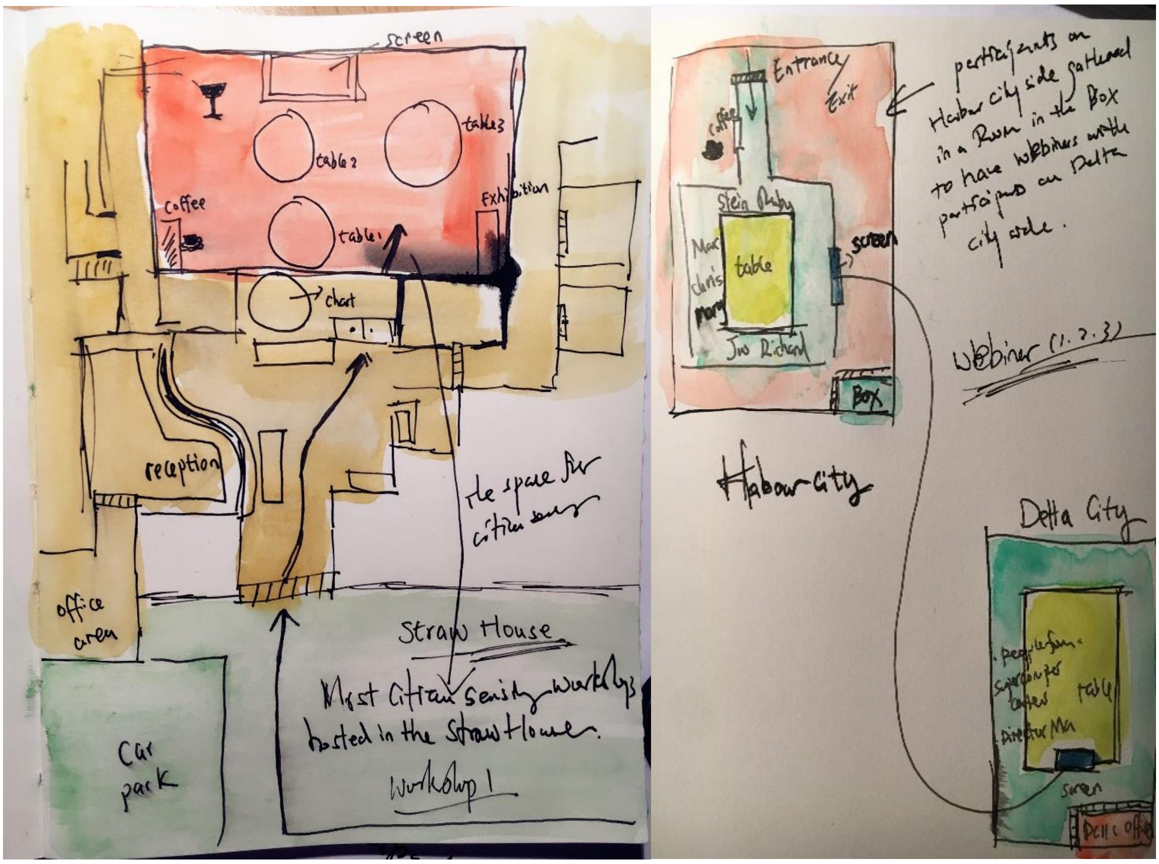
I applied a colour coding system to take observation notes. The photograph above is the first page of my observation notebook which companied with different colour pens and stickers. The Chinese characters on the upper right side describe the purpose of this notebook. The different colour assigned to different colour pen and stickers. For example, I use a black colour fountain pen to scribbles notes and use a pencil to write down my initial thoughts/analysis. I also use different colour stickers to highlight different stages and things in the fieldwork. The white sticker represents “pre-field preparation”. In this section, I often write down the time and place of the event. If the event had schedule provided, I often conduct some initial analysis of the schedule and write down what I want to find out from the event? The black sticker indicates “a space for taking notes in the field”. The blue sticker used to highlight “references” that people mentioned in the field that I need to look up after the fieldwork. The red sticker emphasis “interesting point” for further analysis. The yellow stickers remind me what kind of “objects/documents” that I collect from the field. It is worth noting; this colour organising system is useful at the beginning of the research. It helps me to form a good habit of data collection and made me more aware of what kind of data I can collect from the field. But, I must admit that taking notes in the field is much messy than this. Especially in the late stage of research, where I am more and more clear about what I want to find in the field. So, I am less applying this colour coding system in fieldwork. My notes become more and more messy.

Appendix 3. Several examples of sketches of settings

(1) The sketch of the layout of the NEXT Lab



(2) The skecth of the settings for Citizen Sensing (left) and Webinars (right) to take place



Appendix 4. An example of the interview checklist

Interview a board member of OPHC

Time: 12:00 am **Place**: The interviewee's office

Purpose:

Data purpose: to understand more about OPHC's history. The network formation in the earlier stage, the result of the diffusion of the vision.

Methodology purpose: snowball method to find out who to interview next.

Procedure:

Introducing the purpose of this research to the interviewee.

Allowing enough time for the interviewee to read the information sheet and sign the consent form.

Negotiate the use of data. (...)

Asking questions:

Semi-structured interview questions:

(1) What is the vision of OPHC?

(2) Where does the vision come from?

(3) Who shapes the idea? Are there are people who have been important at different times?

(4) Compare with the normal smart city, what is the most innovative aspect of OPHC?

(5) How did different parts of OPHC come together? Were there any difficulties in create shared visions?

(6) Were there any moments of disagreement or difficulty? What happened? And were those questions negotiated?

(7) How did the network form around OPHC? Why are these institutions involved? Why not others? Was there any disagreement about it?

(8) Have there been any particular turning points or key moments in OPHC's history? What are these? Why so important?

(9) Who else should I talk to in order to understand more about how OPHC has developed and how partnerships have been developed?

(10) Do you have any materials/documents that I can have a look at about OPHC's history?

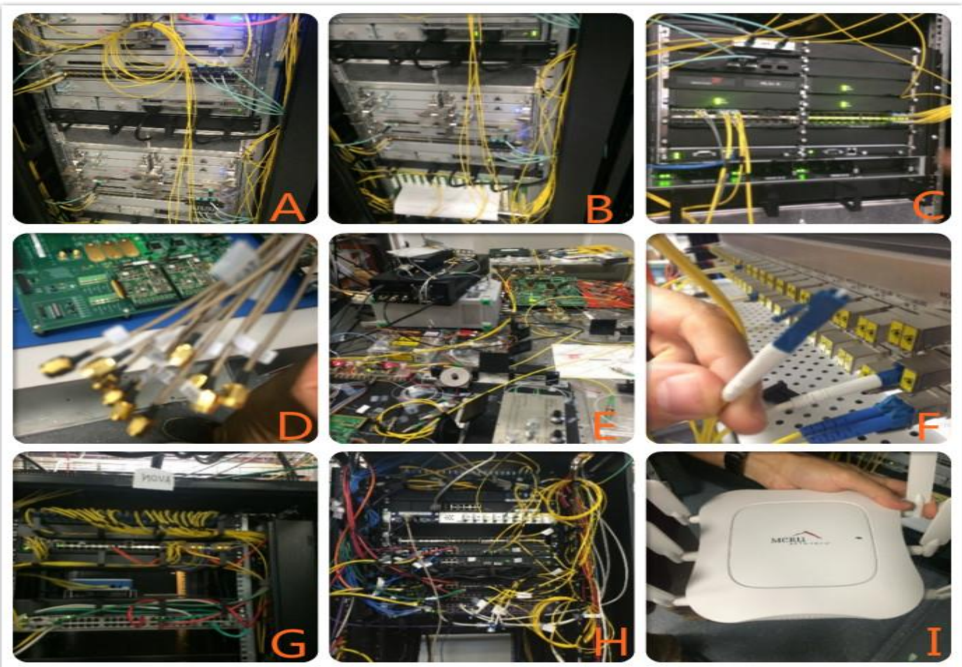
Is there anything else you think I should know about OPHC that I've not asked about?

Appendix 5 An example of the research diary

Time: 05/08/15 **Location**: The Next Lab **Guide/Contactor**: Ian

I had an appointment with Ian this afternoon. He agreed to give me a guided tour in the Next Lab. Around 3 pm, I bought two ice latte to visit him in the lab. It is the first time for me to visit the Lab. I felt a bit nervous. The lab located on the Ground Floor of a building. Luckily, I met a friend at the corridor, and he let me get through the two-locked door to enter the Lab. The Lab has a very big office area. It seems that there are many different types of research groups there. Very few familiar faces. Iran's desk placed at the back of the office, which has an excellent view of the whole office. He noticed that I arrive. After greeting, I sit down and introduce the aim of this study. I tell him that I had already contact Susan a few months ago, but until recently I sort out the ethical forms for this research and be able to come to collect data. In order to give an inform consent about my research, I gave him the information sheet and the consent form. Then I explained what I want from today's tour. For example, I want to understand the infrastructure of the OPHC, how many people in the Lab involved in, and what is the future agenda? If I want to conduct the ethnographic research in the Lab what is the possibility and how to negotiate access?

Then he brought me to the Lab. The Lab located at the end the office, behind a locked door. When I get into the lab, the first feeling is a bit little chilly because of the equipment of need low temperature. On the right side, there are two big blocks of servers which haven't fully installed yet. He starts to give me a tour. I guess he has his order, which he introduced this to many visitors. He introduced that there are seven layers of the infrastructure, that OPHC only deals with three layers of the infrastructure. Get the permission, and I took the photos.



For the programmability, he introduced me the FPGA; it is a bit like the Raspberry Pi or Arduino Board (picture D and picture E are FPGA and their location). It is the first time for me to see the real fibre (picture F). It is so thin. Unbelievable! It like the white hair. It connected the Lab to the three main nodes, I always read so, but do not know how it actually works. The Fibre connect to the other part of the world, the one in the UK called Ja.net. The one to the world called GEANT. I still vividly remember last time Susan told me so. The fibre not only connects to the other part of the world, but it also connects to Harbour City and a supercomputer in the fourth floor of this building *(picture G, the point connecting to the supercomputer). I wonder, how they put the fibre, Ian told me they do not need to do the ducting. There are ducting people to do it, and they only need to know where the two ends are.*

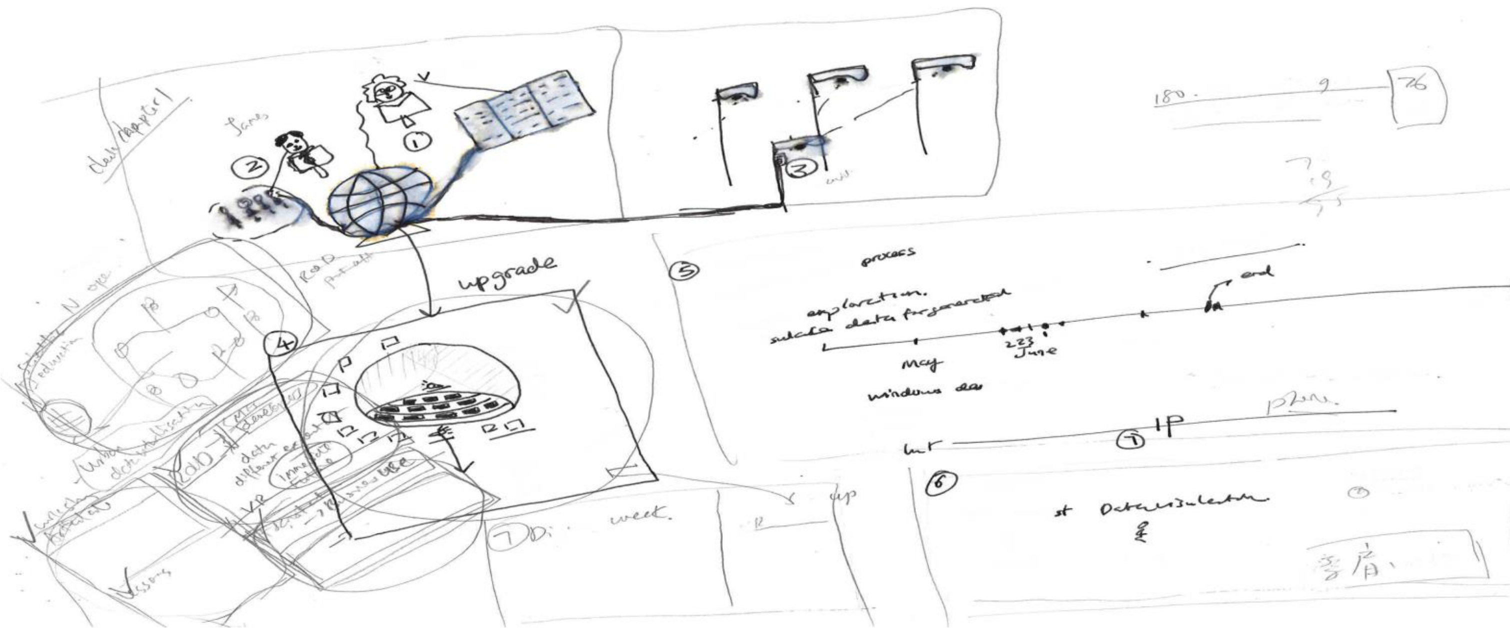
I learn the new concept today, which the 'active node'. There are there other 'active nodes' distribute in DOCK, Science Museum and BOX. Then, he introduced me the wireless and sensor layers. Regarding the wireless, he mainly highlights four types of technologies, 4G, LET-A, Wi-Fi, 802.11AC, Blue Arrow' Wig Gig. 4G we all know is the four generation of mobile network, 802.11 AC he shows me the retour (the picture I). Blue Arrow's backhaul not only allows users to access but also it can talk to another Wig Gig. The reason why chooses Blue Arrow. According to Ian, it is because the lab has some cooperation with Blue Arrow before. So both parties know each other before.

At the end of the Lab tour, I asked him how many people involve in the OPHC from the Lab now; he said only four: himself, David, a marketing person, and an HP who consultant contact. I mentioned that I am going to study the innovation process. He then introduces me to David, who just come to OPHC for a week and trying to set a deadline for OPHC. I had a very short chat with him to understand OPHC's calendar; he will be trying to figure it out in the next week, I thanked him and sent him an email afterwards.

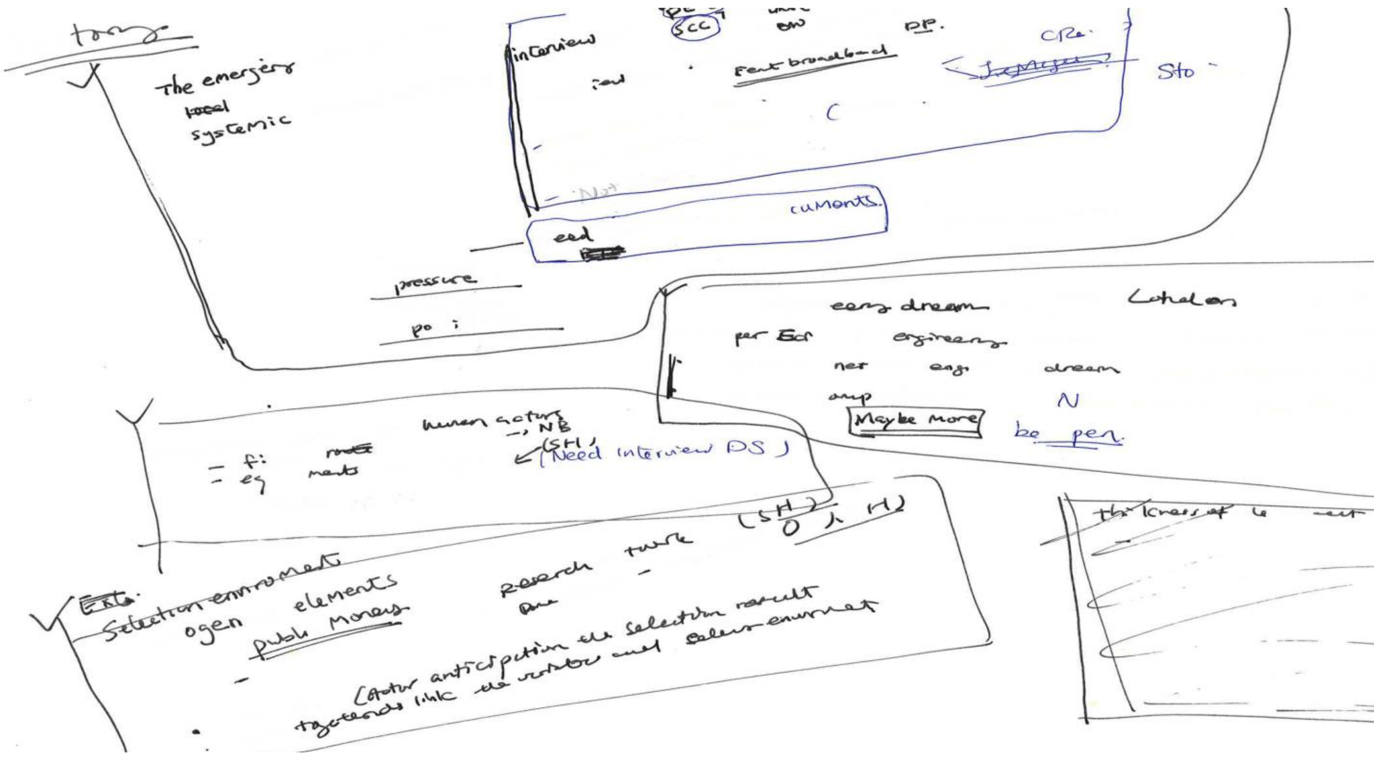
I say goodbye to Ian and make sure he signs the consent form. He sends me outside the Lab. I left the lab, feel clearer about technologies, but very tired…

Appendix 6 Examples of using drawing to assist analysis

(1) Using drawing to analysis the history of Data Dome



(2) Using drawing to figure out the history of OPHC



Appendix 7. The information sheet and the consent form

Information Sheet

My name is Yin Jingwen, and I am a PhD student at the Graduate School of Education, University of Bristol. The PhD project titles, *an ethnographic study of a smart city in the making*, is going to study the social innovation through Open Programmable Harbour City (OPHC). I am interested in how different types of technologies work together to make OPHC; and what is role of vision in the innovation process; and what opportunities there for citizen participation.

The outcomes of this study will contribute to understand better the role of high technology innovator in reshaping the future city landscape. Vision's role in a socio-technical innovation process. It will also help us understand better how citizens may be involved in a high technology city innovation.

In order to archive the research objective, this research will deploy an ethnographic approach and adopt the participant observation and interview as research method. The project follows the ethical guidelines of the British Educational Research Association (BERA) and the Data Protection Act of the United Kingdom. It has already been ethically approved by the University of Bristol's Graduate School of Education.

This means that if you decide to take part:

- The researcher will take fieldnotes and photographs during the observation. Audio-recording the interview for research purpose.

- You are granted the right to withdraw your contribution from the project at any time. You do not have to state a reason for doing this.

- All data will be treated confidentially and stored on devices secured by personal passwords. The fieldnotes and any prints will be kept in a locked filing cabinet.

- Since there is only one Open Programmable Harbour City, the researcher cannot guarantee the participants' fully anonymity. You should know that it is possible to be identified in my writing. But, I will conceal your real name.

- The research is expected to be reported as research thesis, presented in conferences and published in academic journals. The participant will send an electronic copy of the complete PhD thesis if they wish.

If you have any complaints about the content of the research and the researcher, the complaint channel is provided:

Professor Keri Facer, Email: Keri.Facer@bristol.ac.uk
Professor Thomas Osborne, Email:thomas.osborne@bristol.ac.uk

For the purpose of transparency, you will be asked to fill a consent form. This form needs to be signed before any observation and interview takes place. You and I will both keep a copy of the signed document
Best Regard,

Yin Jingwen
Doctor Researcher
Graduate School of Education, University of Bristol
Email: jwyin1130@gmail.com
Mobile: +44(0) 7427662177

Consent Form

An Ethnographic Study of a Smart City in the Making

Please tick if you agree

1. I confirm that I have read and understand the information sheet explaining the study and I have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw from participating at any time, without stating a reason for doing this. ☐
3. I understand that the researcher will take fieldnotes and photographers during her participant observation. ☐
4. I understand the researcher will make audio recordings of all interview for research purposes. ☐
5. I agree to take part in this study ☐

Signature of the Participant:

Name:
Date:

Researcher's Signature:

Name:
Date:

Appendix 8 Other empirical data

(1) Different people's previous experience in relation to "experiment"

Civil servant experiment with new ideas

"In the late 1990s, my original job was around finding out what people and city felt about their priorities. We did that by using lots of questionnaires and post to people. People filled them in and sent it back. We very quickly said that 'oh! why do not we use technologies (...)'. That is when we get involved. Very quickly, we get involved in democracy project using technology (...). Because we are a pioneer, the other pioneers sort of find us (...). Lots of people came to us and said 'well, can you trial our products? New ideas? (...)"

A senior civil servant from the Harbour City Council

Experimenting with fibre, wireless, wearable tech

"Well, I been involved in getting experiment with this high-speed network for a long time (...). I persuaded the network provider to lend us the use of fibre in 1990s. We built an experimental network (...) One commercial organisation actually be able to make it commercially (...). And we did a lot of experiments, partly around this earlier network, and anticipating the arrive of this much faster wireless connectivity (...). We were exploring things like wearable technology (...). So, these were the sort of things that we experiment with. Putting interesting technology in people's hand and exploring what could be done (...). We all have struggles of designing things, how do you take into all those factors. This is why you need those sort of experimental test-bed (...)"

A computer scientist from the local University

Experimenting in the real life

"Another reason for us to involve in OPHC, probably about 2008, we joined the European network of the living lab (...). We set the community living lab. We are not testing things about people, but testing things with people (...). There was a very important phase for R&D research experimentation that is experiment in community with real people. But, not just they give tech, trial, and you delivered. We were done some of this, where people deliver technology and trial. That's ok. It's better, in my opinion, to work with people, and researchers to design a solution. So, when we first get involved, the first project we did in the living lab was an earlier smart metering project (...). It not a smart meter project for me because we are not interested in smart metering per se. We were interested in working with people to understand what was going on? How do we understand it? We also start to understand the value of data, citizen generating things (...)"

A co-director of the Straw House

(2) An imagination of a possible use case for the experimental research testbed

In order to deliver the experimental research testbed, many ideas pop-up. One idea is to use the network to establish an educational project. There was an idea to link fibre to the Dome in the Science Museum and the supercomputer facilities in the Harbour City University. This linkage suggests to allows students at the ages of secondary education to access the High-Performance Computing from the Dome (Interview with Luke, 15 September 2016).

(3) Emma and MiniCat's engagement

MiniCat is a U.S multinational technology company. The company has a department to co-design creative project free for society. One engineer Emma found the Data Dome project interesting and gain the company's permission to conduct development for the Dome. Emma's suggestion was approved by the company, and eight engineers were assigned to design a gesture control application for the Dome (Informal Interview with Emma, 08 October 2016).

(4) The intermediary and system intermediary actors

Several intermediary actors can be identified in the vertical diffusion process of OPHC. This includes smart city-related standardisation organisations and research institutions. The former mainly refers to a U.S based SDN standardisation organisation, a UK open data standardisation organisation, and a UK Internet of Things (IoT) organisation. Standardisation organisations are important for aggregate OPHC to the global smart cities niche because knowledge production about smart cities at a local level is a collective good. Standardisation organisation responsible for maintaining collective technical knowledge. They could help to avoid free-rider. Regarding research institutions, they often hired by other firms to compare smart cities experiences in different locations and draw some general conclusions. In the case of OPHC, a research institution O3 was hired by a Chinese multinational telecommunication company to produce a UK smart city index. O3 mapped the smart city development in the UK. OPHC was included in the report and it was regarded as a UK smart city leader.

Three system intermediary actors aggregated experiences from OPHC to a network level and broker relationship between different parties. The first system intermediary actor was industry associations. They facilitate the circulation of knowledge, articulate problem agenda, and exchange experiences in nowadays' smart cities making. There was an industry association calls Digital Forum who is a smart city business advocator. It hosted global scale smart cities conferences to attract smart city actors around the world to participate and share their experience. In the process, the association selected valuable local practices and distilled some important cases to circulated at a global level. OPHC was one of its chosen cases. The second type was the UK government agents. This includes the Future City Radar (FCR) and the Foreign and Commonwealth Office (FCO). They help to distil valuable local lessons to a national level. For example, in the story of Data Dome, we can see that FCR actively participated a series of workshops to explore the use case of Data Dome (see more in Chapter 6). It collected useful lessons from the Data Dome to understand the exportation possibility of smart technologies. In the story of the Delta City that we will read later, FCO funded a smart city project between Harbour City and Delta City (China). FCO aimed to collect valuable lessons from the communication process and spread the lesson at a national level. The third type was community organisations. Straw House is an example of this type of actor. As we can see in Chapter 6, Straw House leads the citizen sensing project. Given the Straw House is part of the international living lab network, the organisation shared its experience of citizen sensing in the network. For example, in autumn (2016), managers of Citizen Sensing project travelled to a living lab conference hosted in Canada and shared its Citizen Sensing project experience with international audiences (Fieldnotes, October 2016).

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